ENGINEERING REPORT

TREATMENT ALTERNATIVES INVESTIGATION AND ASSESSMENT FOR TRICHLOROETHENE (TCE) REMOVAL AT MUNICIPAL WATER TREATMENT PLANT #1

FOR

FORREST CITY WATER UTILITY

CITY OF FORREST CITY, ARKANSAS

Prepared by:

US Army Corps of Engineers ®
Omaha District

August 2009

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1 INTRODUCTION

A request was made by U.S. Environmental Protection Agency (U.S. EPA), through an Interagency Agreement (IAG) (#DW-96-95045501-Addendum 3 to Scope of Work) between the EPA and the U.S. Army Corps of Engineers (USACE), to provide a basic engineering investigation and evaluation of applicable treatment alternatives for Trichloroethene (TCE) treatment at the City of Forrest City, Arkansas Water Treatment Plant (WTP) #1. Water supplied by four (4) of the seven (7) wells serving this plant have had historical detections of TCE contamination since February 2001 until present. The TCE concentrations at existing wells No. 1A and No. 5 have caused the Forrest City WTP finished water quality to exceed the Maximum Contaminant Level (MCL) for TCE in drinking water of 5 micrograms per liters (µg/L) or part per billions (ppb).

The intent of this report is to furnish the stakeholders of the Forrest City Water Utility a document to assist them in decision-making, fiscal and logistical planning for implementation of recommendations suggested herein to bring the water supplied by WTP #1 within regulatory compliance for TCE concentration. The recommendations in this report are made to address the best TCE treatment option in terms of cost, applicability and compatibility with the existing physical and chemical unit operations at the Forrest City WTP #1. This report is a summary of the review and evaluation of the best and commonly used TCE removal technologies applicable to systems of this type.

A site visit and review of the system components, as well as coordination and conversations with the Forrest City Water Utility Staff and City Engineer was an integral effort in completing this evaluation. Recommendations made in this report are intended to be consistent with the objectives of the City of Forrest City in providing the best water quality possible to the residents and concerns of that community.

2 EXISTING CITY OF FORREST CITY WATER SYSTEM DESCRIPTION

2.1 Wells/Water Treatment Plants

Forrest City's Water is supplied from three different well fields each with a separate water treatment plant. The water treatment plants are referred to as Water Treatment Plant #1 (Sanyo Rd), Water Treatment Plant #2 (Division Street) and Water Treatment Plant #3 (Northwest of Federal Correctional Institution-FCI). All three plants provided at least chlorination and fluoridation of the groundwater supplied to them. The City of Forrest City's current total water supply capacity is approximately 13.0 MGD. Water Treatment Plant #1 provides the largest portion of this capacity, with groundwater well capacity of up to 7.78 MGD, which represents almost 60% of the total water supply for Forrest City. Water Treatment Plant #2 and Water Treatment Plant #3 provide the remainder of the water supply capacity of 2.66 MGD and 2.88 MGD respectively. Only the water produced from the wellfield serving Water Treatment Plant #1 has had any historical or recent detections of TCE contamination. A summary of the City of Forrest City Water System Capabilities as provided by the City Engineer is summarized in Table 1: Water System and Capacities.

Table 1: Water System and Capacities

Water Supply	Number of Operational Wells in Field	Total Well Capacity to Plant (MGD)	Total Well Firm Capacity[1] to Plant (MGD)	Total Finished Water Pumping Capacity (MGD)	Total Pump Firm[1] Capacity (MGD)
Water Plant #1 (3120 Sanyo Rd.)	7	7.78	5.83	6.77	5.08
Water Plant #2 (1400 N. Division St.)	4	2.66	2.00	4.32	3.24
Water Plant #3 (NW of FCI)	1	2.88	2.88	2.88	2.88
Summary	12	13.3	10.0	13.97	10.48

Note: 1. Firm Capacity is calculated by the Arkansas Department of Health as 75% of Total Capability

2.2 *Water Distribution/Storage*

The Forrest City water distribution system is served by five (5) water storage facilities located in three (3) separate pressure zones that establish the delivery pressure in the system. Pressure Zone 1 is served directly by the high service pumps from Water Treatment Plant #1, the 1.60 MG Kittle Road Standpipe Tank and the 1.0 MG Fletcher Road Standpipe Tank as well as the Federal Prison elevated storage tank. Overflow elevation of the standpipes is 442 MSL.

Pressure Zone 2 is established by two 1,000 gpm booster pumps and the 200,000 gal Kittle Road elevated water storage tank. Overflow elevation of the elevated storage tank is 505 MSL. Pressure Zone 3, which covers the rural area outside the City, is established by two 250 gpm booster pumps and the 100,000 gallon Newcastle Road elevated water storage tank with an overflow elevation of 542 MSL.

Part of the water distribution of the Forrest City Federal Correctional Institution is directly supplied by Pressure Zone 1 and another part by the 750,000 gallon Prison elevated water storage tank. Well 10 supplies Water Treatment Plant #3. The operating pressure of this system is established by the water levels of the Prison tank and the well pump. A summary of Forrest City Water Storage Facilities is provided in Table 2: Water Storage Facilities.

Table 2: Water Storage Facilities

Pressures Zones/ Facilities	Capacity (MG)	Ground - Overflow Elevations (MSL)	Pumps "On" Elevation (MSL)	Pumps "Off" Elevation (MSL)
Pressure Zone1				
Kittle Rd Standpipe	1.6	387 - 442	432	441
Fletcher Standpipe	1.0	369 - 442	436	441
WP #1 Clearwell	0.21	252.5 - 262.5 (21,092 gal/ft)	258	262
WP #2 Clearwell	0.10	255 - 274 (30 ft diameter)	270	273
Prison Tank	0.75	240.5 – 426.5	407.5	426
Pressure Zone 2- served by two (2) 1,000 gpm pumps				
Kittle Rd Elevated	0.20	396- 479/505	501	504
Pressure Zone 3- served by two (2) 250 gpm pumps				
Newcastle Rd Elevated	0.10	418 - 518/542	537	541

3 CITY OF FORREST CITY WATER TREATMENT PLANT # 1 (WTP #1) & WELLFIELD

3.1 Location

The City of Forrest City WTP #1 is located on the northern edge of the City at the northeast corner of Eldridge Road and Industrial Road, just north of Interstate I-40. The physical address is 3120 Sanyo Road. The seven (7) wells serving WTP #1are located south and west of the treatment plant and just north of Interstate I-40. A site plan indicating the location of the plant in relationship to the wells is provided in Photo 1: City of Forrest City Water Treatment Plant #1 and Wellfield Site.

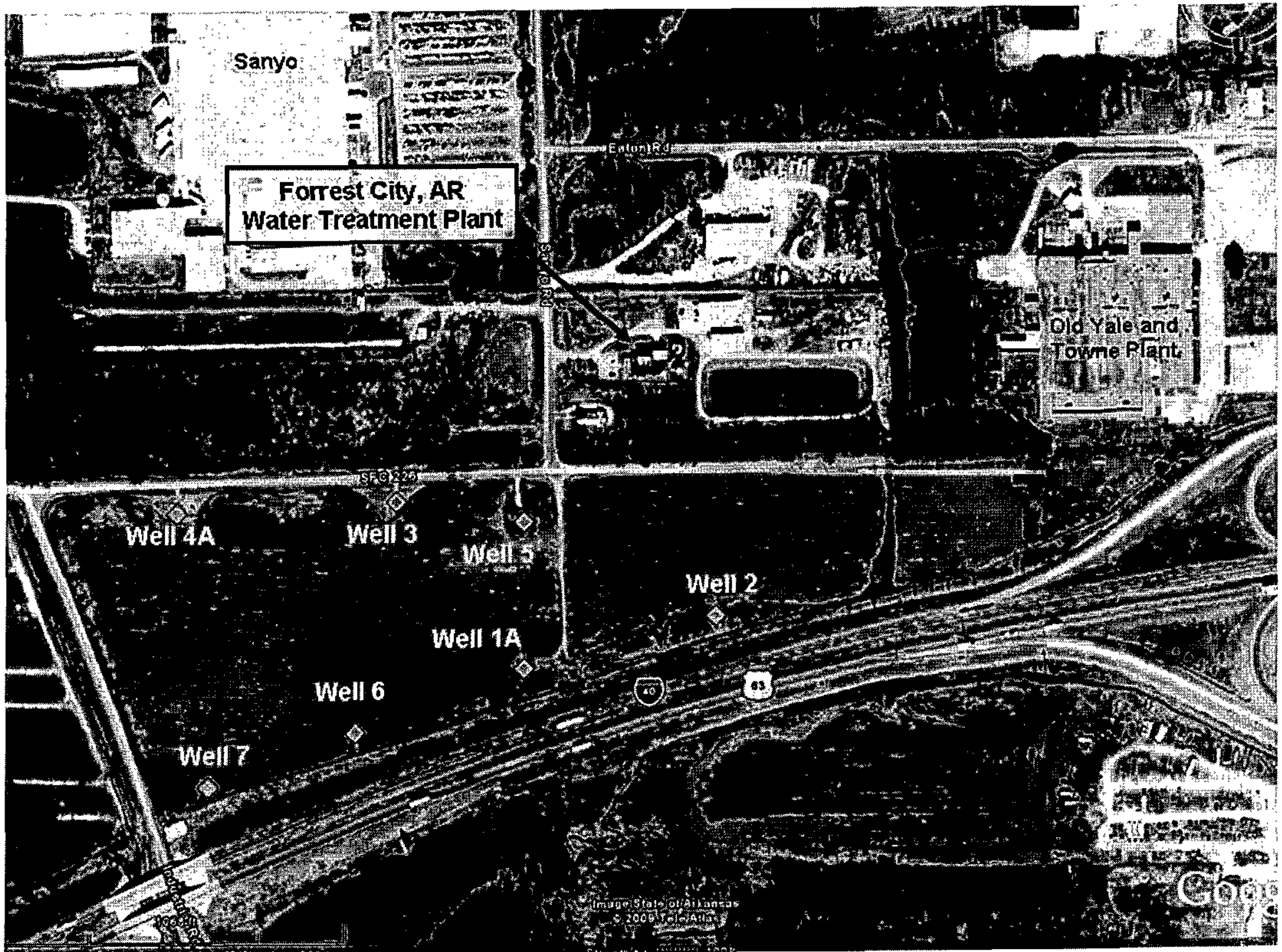

Photo 1: City of Forrest City Water Treatment Plant #1 and Wellfield Site

3.2 Water Supply and Quality

3.3 Wellfield

Seven production wells (Wells Nos. 1A, 2, 3, 4A, 5, 6, and 7) provide the water supply to the Forrest City WTP #1. Wells No. 5 and 7 are also designed to by-pass the Plant and to pump directly into the water distribution system during an emergency condition. Each of the wells is equipped with a vertical turbine pump and associated discharge piping and valves. Photographs of the wells serving Water Treatment Plant #1 are provided below:

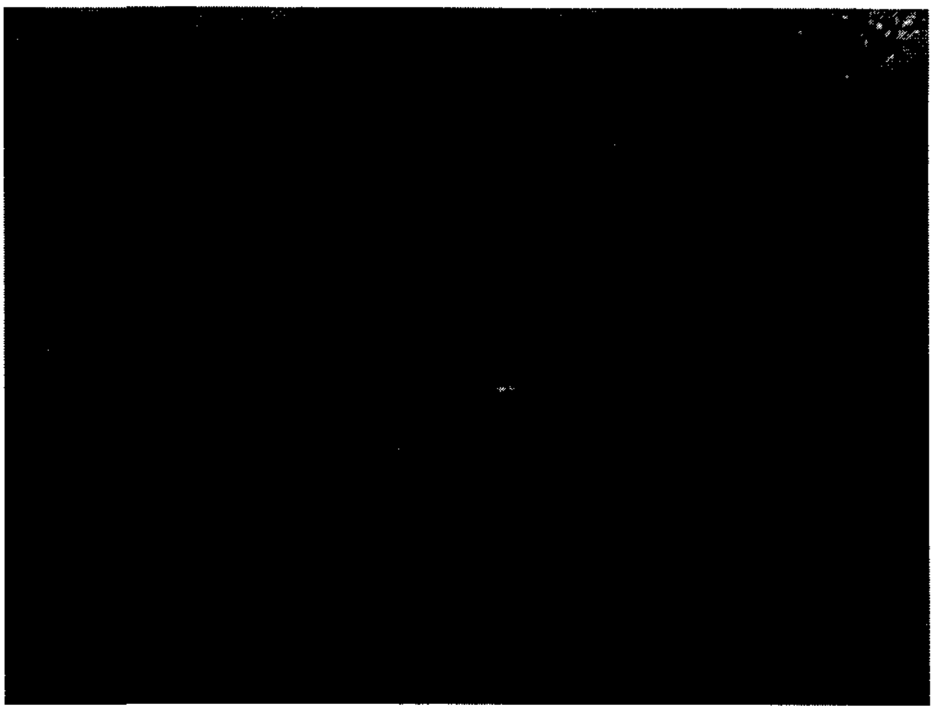

Photo 2: Well #1A

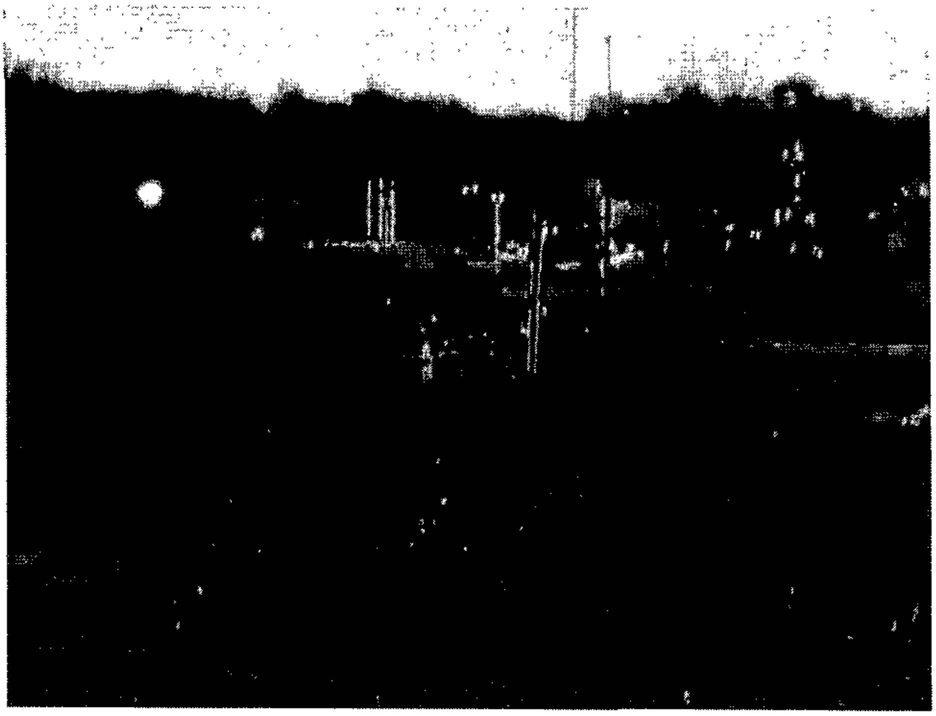

Photo 3: Well #2

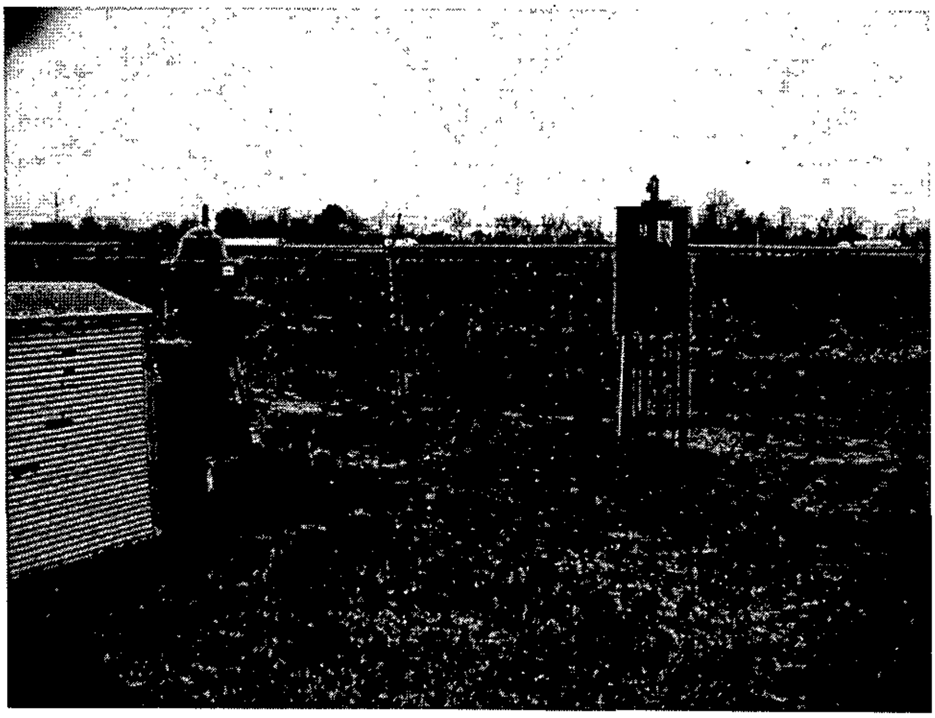

Photo 4: Well #3

Photo 5: Well #4A

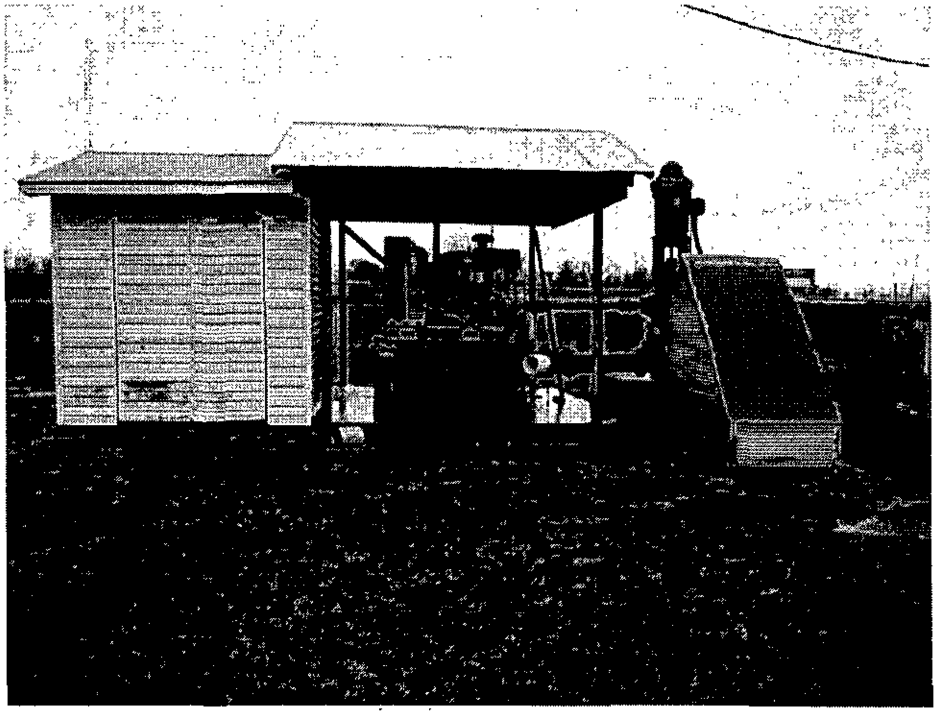

Photo 6: Well #5

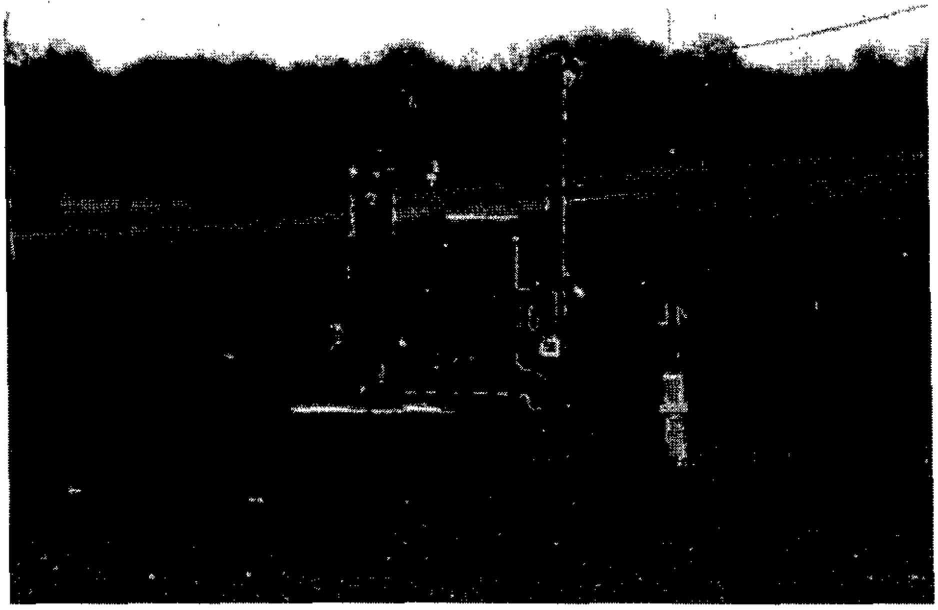

Photo 7: Well #6 or #7 (Similar Construction)

The total well water supply capacity is 7.78 MGD. The Plant maximum pump capacity is about 6.77 MGD (with the three HS pumps operating). During normal operation, one HS pump is offline, allowing the Plant to operate up to 5.0 MGD, which is equivalent to about five wells operating at 700 gpm each.

3.4 General Groundwater Quality

A recent analytical water quality test performed in March 2009 indicates that the hardness level of the groundwater produced by this wellfield has increased from the initial sampling done in 1975 of 100 mg/l (as $CaCO_3$) to 212 to 352 mg/l (as $CaCO_3$). This most recent sampling event also indicates that the Iron and Manganese levels are below the required maximum contaminant levels (MCL's) for secondary water drinking standards. The pH of the groundwater was about 7.1. A summary of the March 2009 sampling event is provided in Table 3: General Water Quality Data below:

Table 3: General Water Quality Data

Well No.	Alkalinity (as CaCO3), mg/l)	Hardness (as CaCO3), mg/l)	Manganese (mg/l)	Iron (mg/l)	Solids, Total Dissolved (mg/l)	Solids, Total Suspended (mg/l)
W1	284	307	0.01	0.31	350	<1
W2	212	240	0.005	0.022	298	<1
W3	274	286	0.005	0.047	330	<1
W4A	344	344	0.005	<0.01	416	<1
W5	252	274	0.005	0.033	344	<1
W6	362	352	0.005	<0.01	424	<1
W7	328	328	0.005	<0.01	416	<1
Method	**SM 2320B**	**SM 2340C**	**EPA 200.7**	**EPA 200.7**	**SM 18th 2540 D**	**SM 18th 2540 D**
Testing conducted 4 March 2009						

3.5 Groundwater TCE Contamination

Groundwater analytical data from February 7, 2001 to May 5, 2009 sampling events indicates the occasional presence of TCE contamination in water samples from existing wells (#1A, #2, #3, and #5) serving Water Treatment Plant #1. As a result, finished water produced from WTP #1 has also contained some level of TCE contamination. TCE concentrations of finished water from WTP #1 have exceeded the MCL of 5 μg/L for TCE occasionally since 2002. See Table 4: Historical TCE Testing Results for a summary of past testing results.

The only consistency in this data is that Wells #4A, #6 and #7 have not demonstrated any detectable levels of TCE contamination. Wells #2 and #5 have exhibited the largest concentrations of TCE with maximum concentrations of 54 μg/L and 36 μg/L, respectively. Maximum TCE concentrations in Well #1A have been below 9 μg/L and Well #3 has been just below the 5 μg/L MCL.

Experience of the staff at Water Treatment Plant #1 has shown that TCE concentrations appear to vary significantly depending upon the wells pumping. Wells not pumped for some time appear to retreat to below MCL or non-detect levels, while contaminated wells pumped appear to increase in concentration over time as they are pumped.

Table 4: Historical TCE Testing Results

FORREST CITY WATER UTILITY

TRICHLOROETHENE TESTING

DATE	PLANT 1				PLANT 1
02/07/01 ADH	0.40	02/03/03 ADH	0.43	05/19/05 ADH	0.99
05/08/01 ADH	0.56	04/29/03 ADH	0.69	08/08/05 ADH	2.30
08/20/01 ADH	1.20	08/12/03 ADH	0.48	10/31/05 ADH	<0.50
10/29/01 ADH	1.20	11/03/03 ADH	1.99	03/08/06 ADH	3.15
02/04/02 ADH	1.20	02/09/04 ADH	<0.50	06/14/06 ADH	2.70
04/22/02 ADH	6.10	04/25/04 ADH	2.10	08/30/06 ADH	2.68
06/25/02 ADH	1.86	09/13/04 ADH	1.00	11/13/06 ADH	3.76
07/08/02 ADH	3.73	11/22/04 ADH	1.62		
10/02/02 ADH	1.45	02/14/05 ADH	<0.50		

	PLANT 1	WELL 1		WELL 2		WELL 3		WELL 4		WELL 5		WELL 6		WELL 7	
01/29/07 ADH	0.72														
05/22/07 ADH	5.10		on		on		on		x		on				
06/05/07 ADH	9.21		on		on		on		x		on				
01/01/06			on		on		on		x		on				
01/01/07			on		on		on		x		on				
			on		on		on		x		on				
08/02/07 ADH	3.88 Post	ND	on	14.2	on	1.55	on		x	8.09	on				
Pre 5.51			on		on		on		x		on				
09/14/07			on		off		on		x		on				
09/19/07 ADH LETTER FROM JEFF STONE SUGGESTING SHUTTING DOWN WELLS 2 & 5															
09/23/07 ESC	ND		on	S1 ND	off		on		x	S1 7.00	on				
09/23/07 ESC			on	S2 ND	off		on		x		on				
09/23/07 ESC			on	S3 ND	off		on		x		on				
09/23/07 ESC			on	S4 ND	off		on		x		on				
09/23/07 ESC			on	S5 ND	off		on		x		on				
09/23/07 ESC		S1 ND	on	S6 ND	off		on		x		on				
09/24/07 ESC		S2 ND	on	S7 ND	off		on		x	S2 ND	on				
09/24/07 ESC		S3 ND	on	S8 ND	off		on		x	S3 6.41	on				
09/24/07 ESC		S4 ND	on	S9 ND	off		on		x	S4 5.54	on				
09/24/07 ESC		S5 ND	on	S10 ND	off		on		x	S5 5.74	on				
10/02/07			on		off		on		x		on				
10/25/07 ADH	ND		on		off		on		on		off				
02/11/08 ADH	1.28		on		off		on		on		off				
03/18/08 AI		8.80	on	ND	off	2.20	on	ND	on	ND	off				
03/18/08 ESC		6.10	on	ND	off	3.17	on	ND	on	ND	off				
04/01/08			on		on		on		on		off				
04/02/08			off		on		on		on		off				
04/21/08			off		on		on		on		on				
05/08/08 ADH	33.70		off		on		on		on		on				
05/12/08			off		on		on		on		on				
05/15/08 ADH	15.00		off		on		on		on		on				
05/21/08			on		on		on		on		on				
05/28/08 AI	4.20		on		on		on		on		on				
05/29/08 AI	4.60		on		on		on		on		on				
05/30/08 ESC/pm	5.55		on		on		on		on		on				
05/30/08 AI 1650	4.70		on		on		on		on		on				
05/31/08 AI 1721	ND		on		on		on		on		off				
05/31/08 ESC/pm	ND		on		on		on		on		off				
06/01/08 AI 2045	ND		on		on		on		on		off				
06/01/08 ESC/pm	ND		on		on		on		on		off				
06/02/08 AI 1645	4.30	ND	on	ND	on	ND	on	ND	on	31.00	on >>>	Water			
06/02/08 ESC/ahd	5.67		on		on		on		on		on >>>				
06/02/08 AI/ahd	4.60		on		on		on		on		on >>>	Plant			
06/02/08 ADH/esc/al	6.09		on		on		on		on		on >>>				
06/02/08 ESC/pm	5.94		on		on		on		on		on >>>	#2			
06/03/08 AI 1806	4.30		on		on		on		on	36.00	on >>>				
06/03/08 ESC	ND	ND	on	ND	on	ND	on	ND	on	30.11	on >>>	Out			
06/03/08 ESC			on		on		on		on	30.78	on >>>	of			
06/12/08 AI	3.90		on		on		on		on	29.00	on >>>				
06/12/08 ESC	5.31		on		on		on		on	32 22	on >>>	Service			
06/18/08 ESC	ND		on		on		on		on		off	ND	on	ND	on
07/01/08			on		on		on		on		off		on		on
07/16/08 ESC	ND	ND	on	ND	on	3.98	on	ND	on	ND	off	ND	on	ND	on
07/16/08 AHD		ND	on	1.22	on	2.41	on	ND	on	ND	off	ND	on	ND	on
08/05/08 AHD	0.70		on		on		on		on		off		on		on
08/26/08			on		on		off		on		off		on		on
09/11/08 ESC	ND	5.14	on	ND	on	ND	off	ND	on	ND	off	ND	on	ND	on
11/04/08 ESC	7.11	8.15	on	54.33	on	ND	off	ND	on	ND	off	ND	on	ND	on
11/04/08			on		on		off		on		on		on		on
11/12/08 AHD	8.08		on		on		off		on		off		on		on
11/12/08 ESC (<0.90)	7.68		on	52.51	on		off		on		on		on		on
11/17/08			on		off				on						
11/21/08 ESC (<0.90)	x	6.98	off		off	4.93	off		on	3.60	off		on		on
11/24/08 ESC (<0.90)	ND	ND	off	ND	off	ND	off	ND	on		off	ND	on	ND	on
11/24/08 AHD (0.50)	ND	0.85	off	0.85	off	2.13	off	ND	on		off	ND	on	ND	on
02/26/09 ESC (<0.90)	x		off		off	ND	off	ND	on		off	ND	on	ND	on
03/04/09 ESC (<0.90)	x	ND	off	ND	off	ND	off	ND	on	ND	off	ND	on	ND	on
03/24/09 AHD (0.50)	ND	x	off	x	off	x	off	x	on	x	off	x	on	x	on
05/05/09 AHD (0.50)	0.66	x	off	x	off	x	off	x	on	x	off	x	on	x	on
05/05/09 ESC (<0.90)	ND	x	off	x	off	ND	off	ND	on	0.00	off	ND	on	ND	on

NOTE: AHD DETECTION LIMIT = 0.50 ug/l
ESC DETECTION LIMIT = 0.90 ug/l

3.6 Water Treatment Plant #1

3.6.1 General Description

Water Treatment Plant #1 (WTP #1) was built in 1973 and was intended to serve as a softening plant for the groundwater produced by the wellfield providing the source. The following photographs depict the exterior of WTP #1.

Photo 8: Forrest City, AR Water Treatment Plant #1 (Sanyo Road). (View looking east)

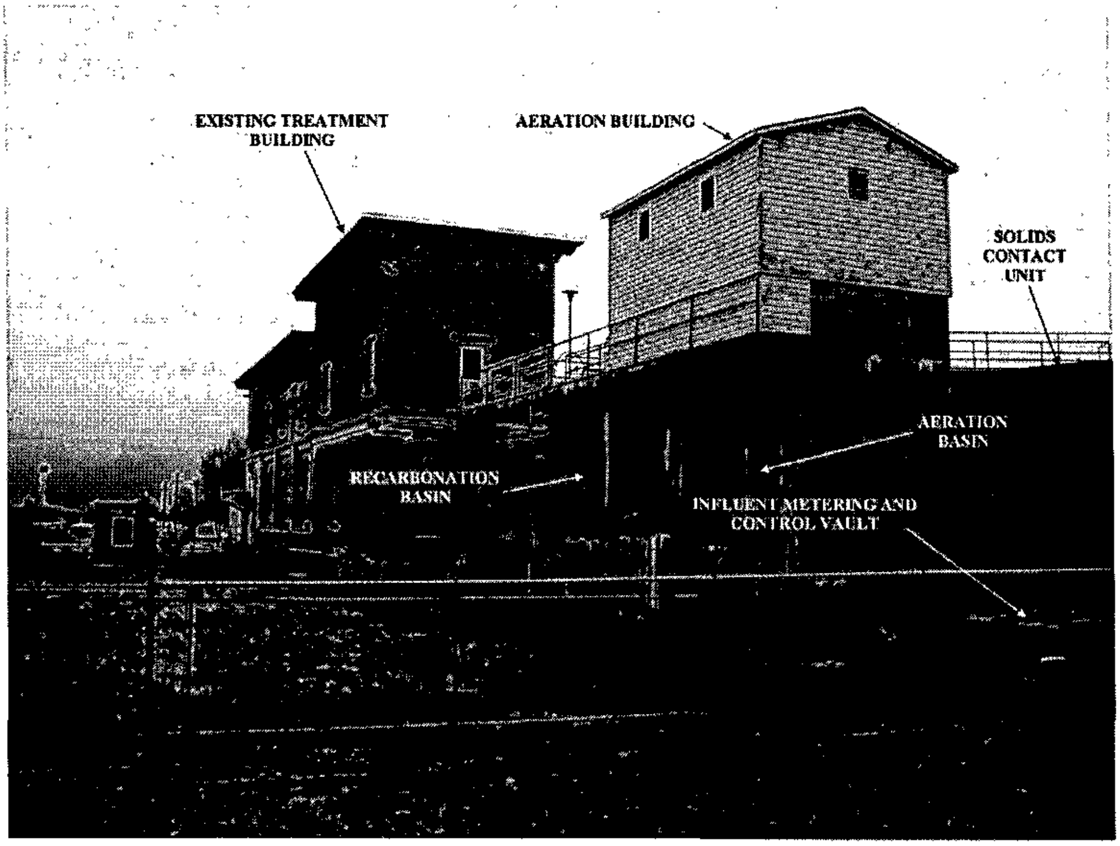

Photo 9: Aeration Basin and Solids Contact Unit (View looking northwest)

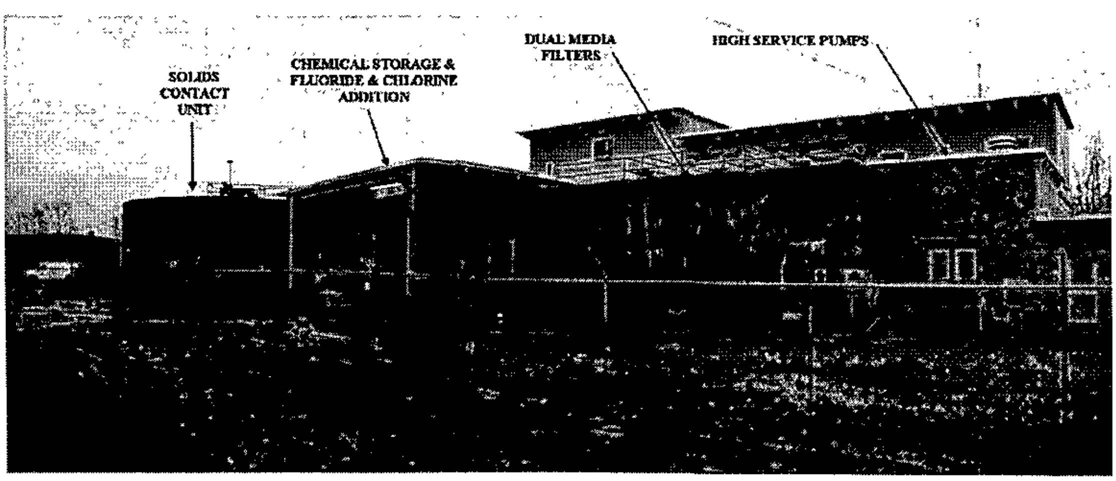

Photo 10: Water Treatment Plant #1 (North Elevation)

Equipment comprising the plant consists of two Infilco Multicone aerators (see Photo 11: Multi-Cone Aerators), a solids contact unit (see Photo 12: Solids Contact Unit), dry chemical feeders for lime and alum addition (see Photo 13: Alum and Lime Feeders), a recarbonation basin (see Photo 14: Recarbonation Basin), three dual–media rapid sand/anthracite filters (see Photo 15: Gravity Dual-Media Filters, Photo 16: Gravity Filter Piping Galley and Photo 17: Gravity Filter Filter Effluent Line), a 220,000 gallon finished water clearwell and three high service (HS) vertical turbine pumps (see Photo 18: High Service Pumps). The plant also includes chlorination and fluoridation equipment (see Photo 19: Chlorination Equipment and Photo 20: Fluoride Feed Equipment).

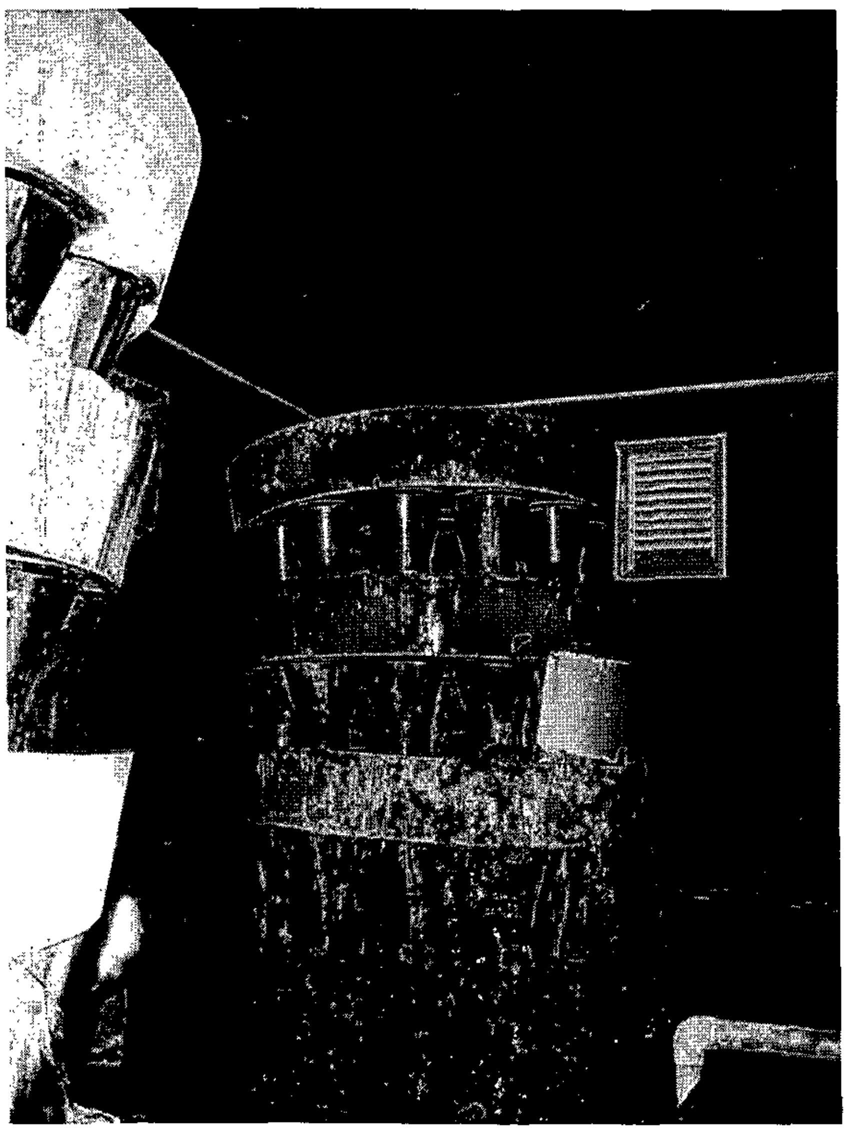

Photo 11: Multi-Cone Aerators

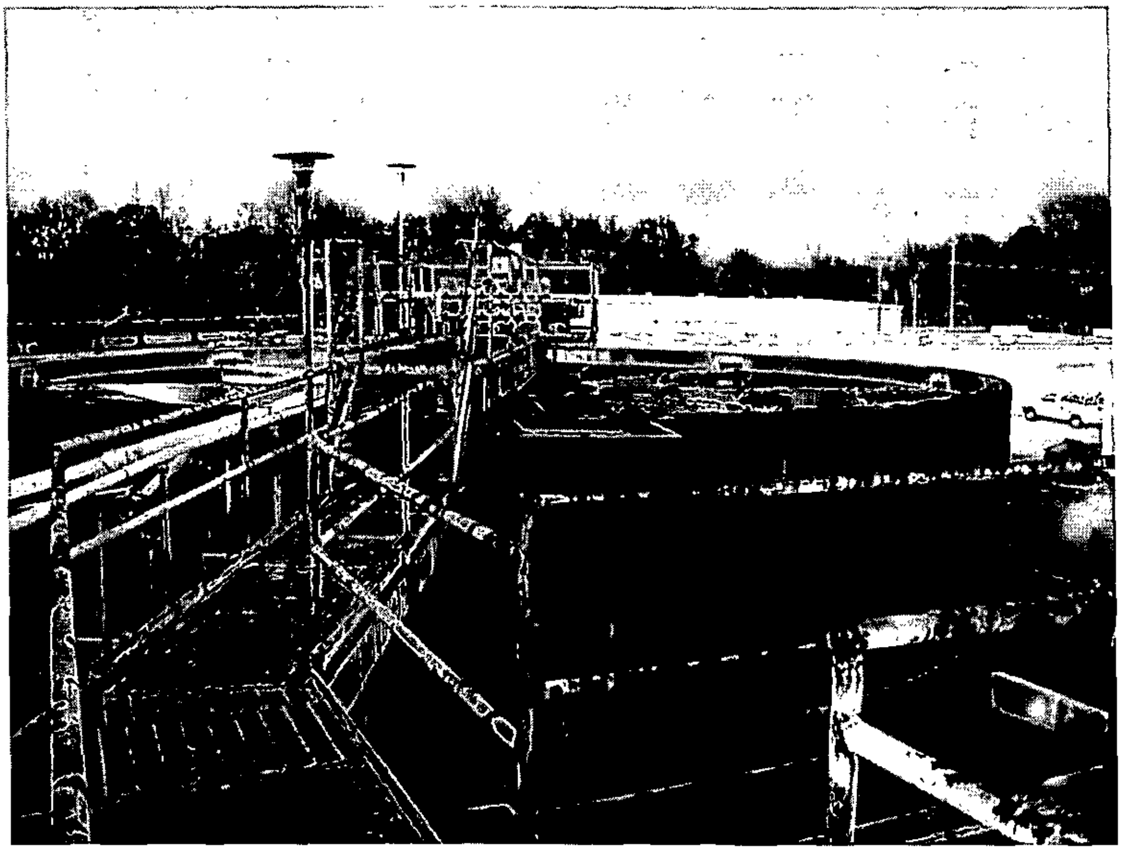

Photo 12: Solids Contact Unit

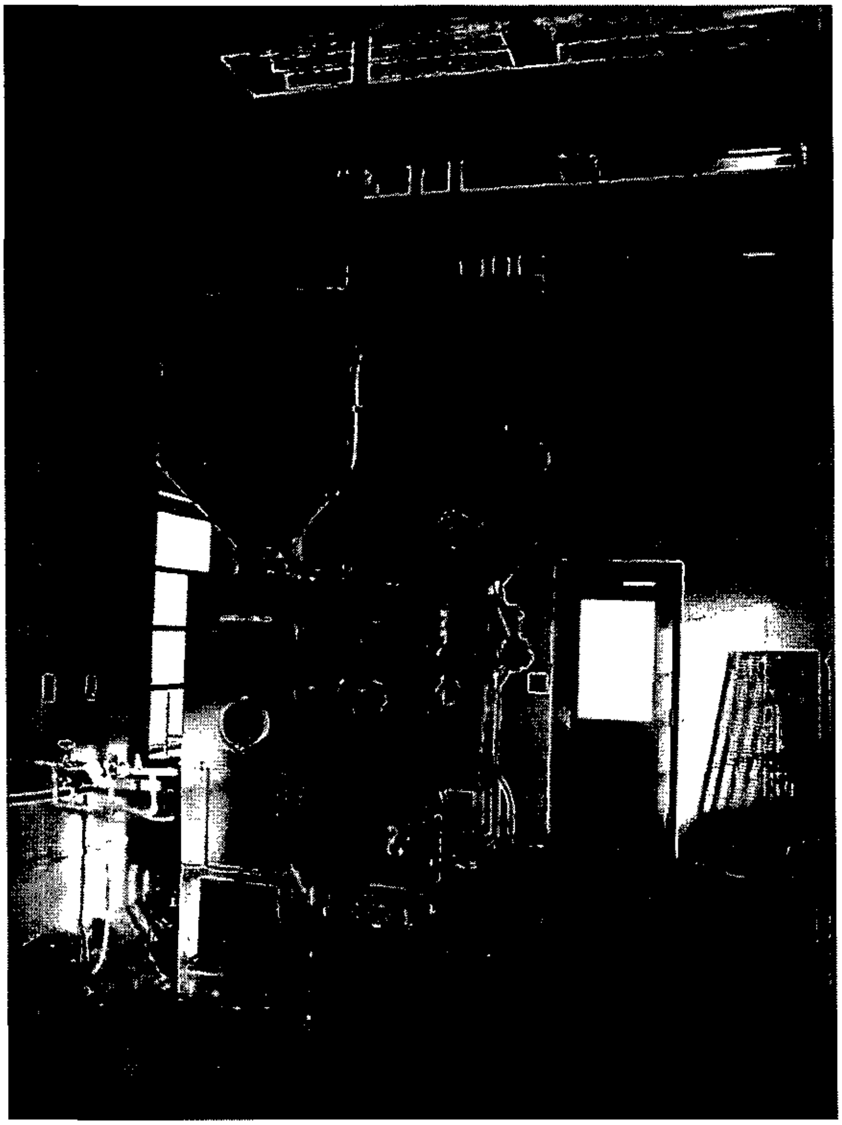

Photo 13: Alum and Lime Feeders

Photo 14: Recarbonation Basin

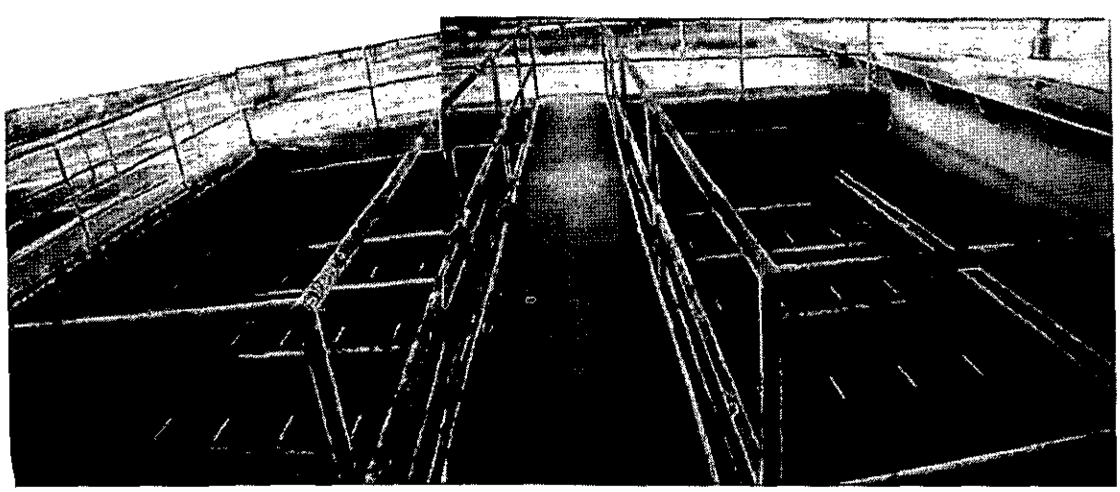

Photo 15: Gravity Dual-Media Filters

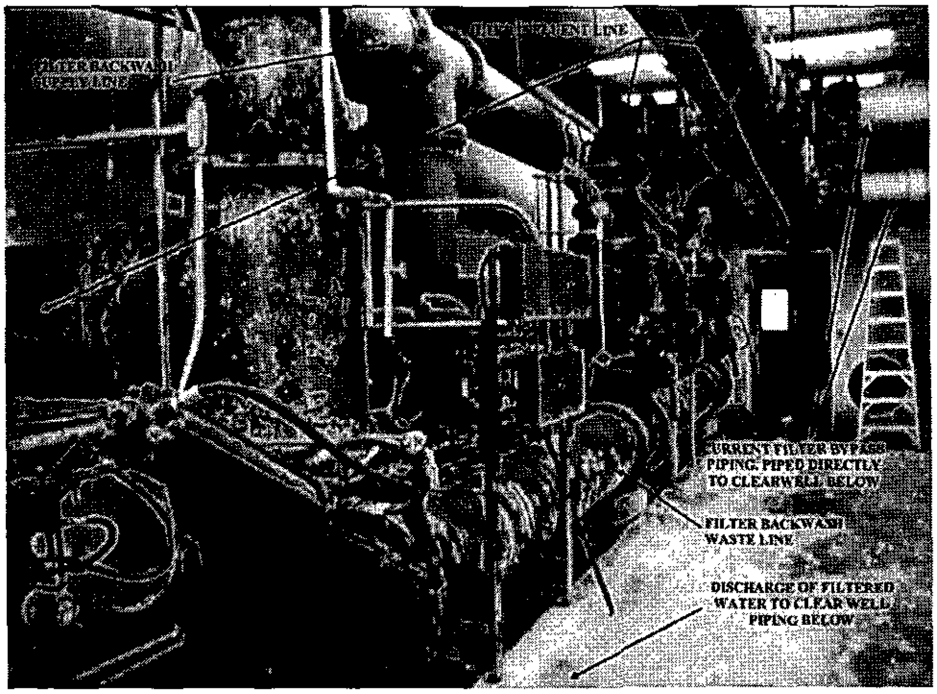

Photo 16: Gravity Filter Piping Galley

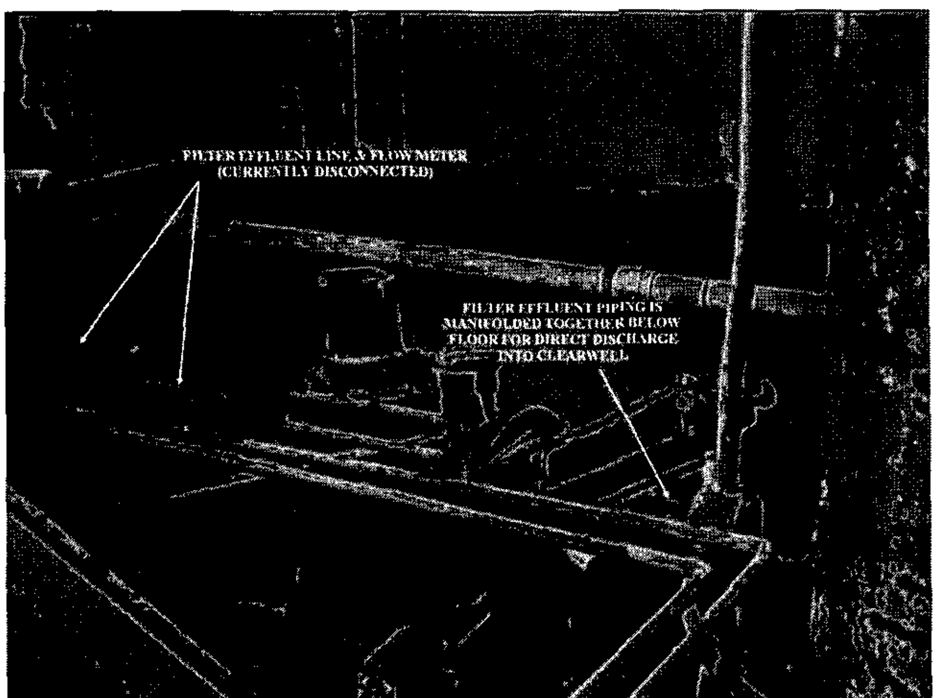

Photo 17: Gravity Filter Filter Effluent Line

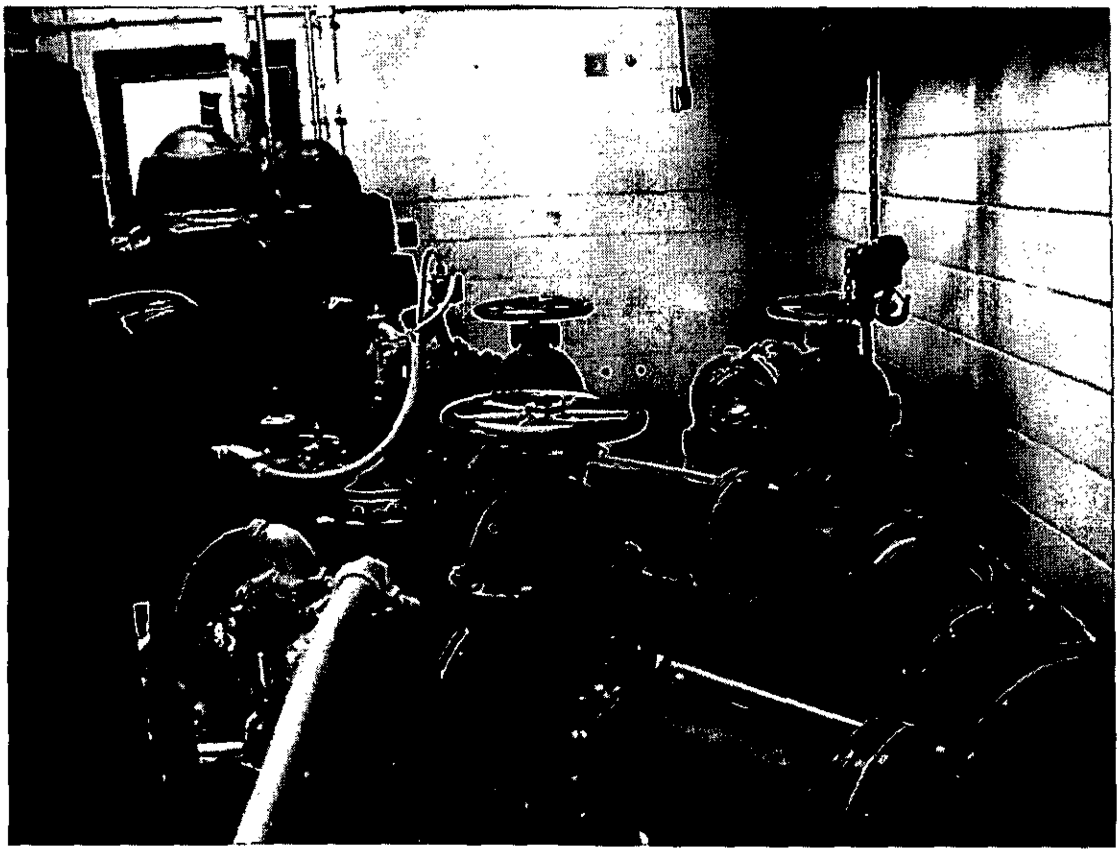

Photo 18: High Service Pumps

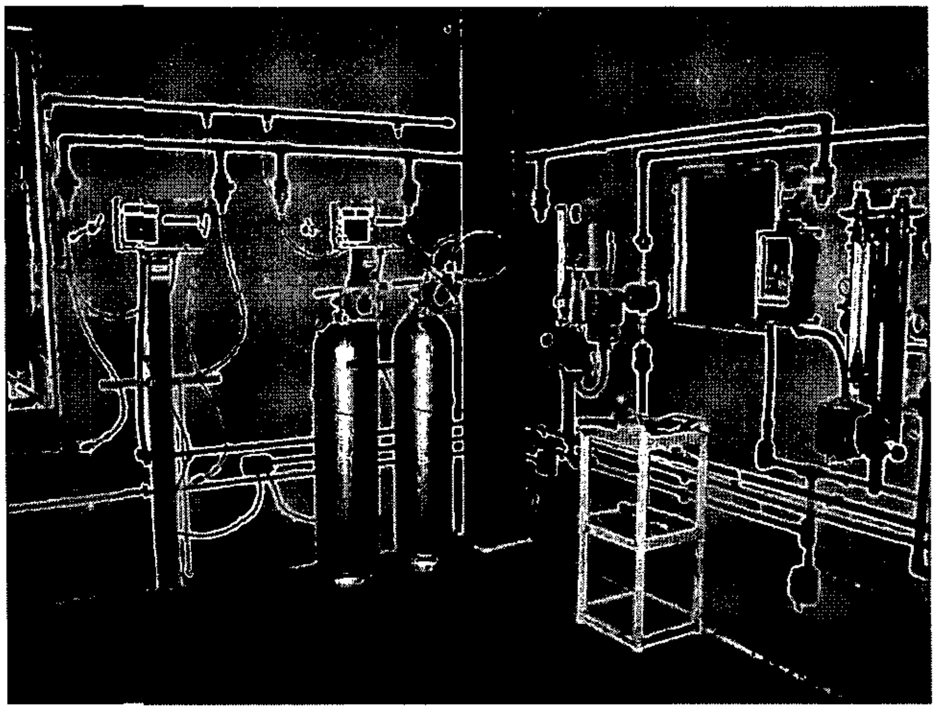

Photo 19: Chlorination Equipment

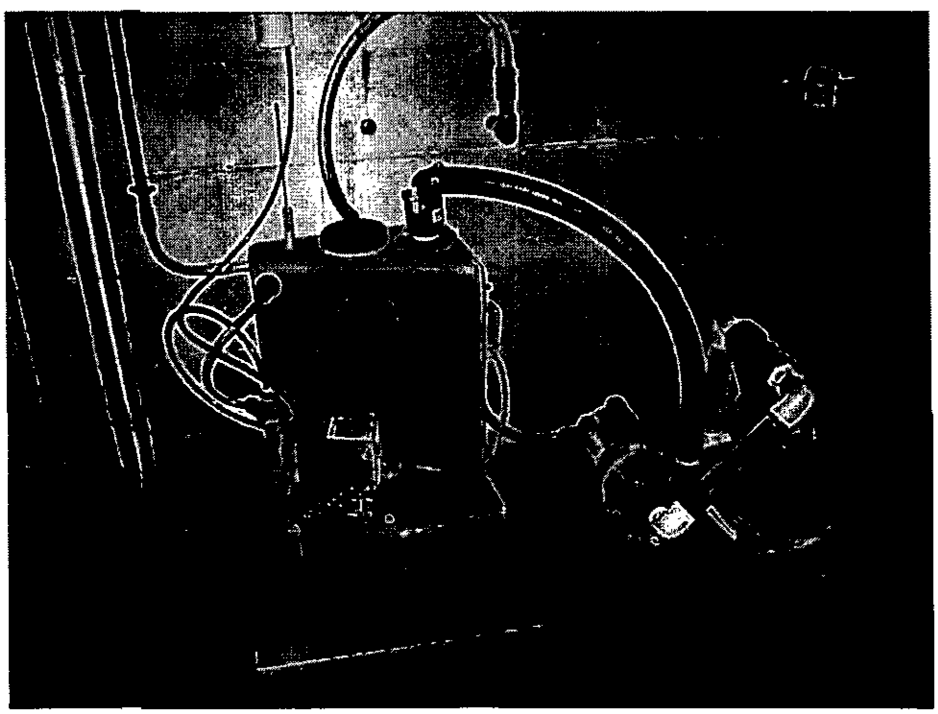

Photo 20: Fluoride Feed Equipment

WTP #1 was originally designed as a lime softening plant rated for 3.0 MGD in anticipation of increasing hardness levels in the groundwater as the formation was pumped over time. The initial hardness of the original four (4) wells constructed in the wellfield was about 100 mg/l (or parts per million, ppm) calcium hardness. Experience in the geographical area for pumping from this aquifer suggested during design that this level would increase over time to a level that would necessitate softening. Although chemical addition (lime and alum) was never used at this plant, the entire groundwater flow produced was hydraulically routed through the plant process units until sometime in 2004. At that time, with hardness levels at increased but acceptable levels, flow was diverted following the aeration process around the solids contact unit, recarbonation basin and filters directly into the clearwell. Current hardness levels are approximately 300 mg/l.

The plant currently provides aeration through the aerators, chlorination for disinfection and fluoridation for dental caries (tooth decay) prevention. Operated in this manner the plant is capable of handling a hydraulic capacity of 5.0 MGD according to Water Utility Staff. Under current operation, the plant uses approximately 20 lbs of chlorine per day for treating 2.5 to 3.0 MGD (2,100 gpm) for disinfection. Free chlorine residual at the plant effluent is maintained at about 1.0 mg/l in order to maintain a 0.6 mg/l residual throughout the water distribution system.

Finished water in the plant clearwell is pumped by three constant speed high service (HS) vertical turbine pumps to the water distribution system. Two of these pumps have a rated capacity of 1,300 gpm (100 HP motors) each. The third pump is rated for 2,100 gpm (200 HP motor). WTP #1 operation and high service pump control are both based upon maintaining water levels in the 1.0 MG Fletcher Road Ground Storage Standpipe.

Provisions for backwash water storage and sludge holding is provided in the adjacent holding cell depicted inPhoto 21: Backwash Wastewater/Sludge Holding Cell.

A supervisory control and data acquisition (SCADA) system is used to operate and view the status of the City of Forrest City water system. The centralized system is located at WTP#1. A screenshot of the control map is provided in Photo 22: Screenshot of SCADA System.

Photo 21: Backwash Wastewater/Sludge Holding Cell

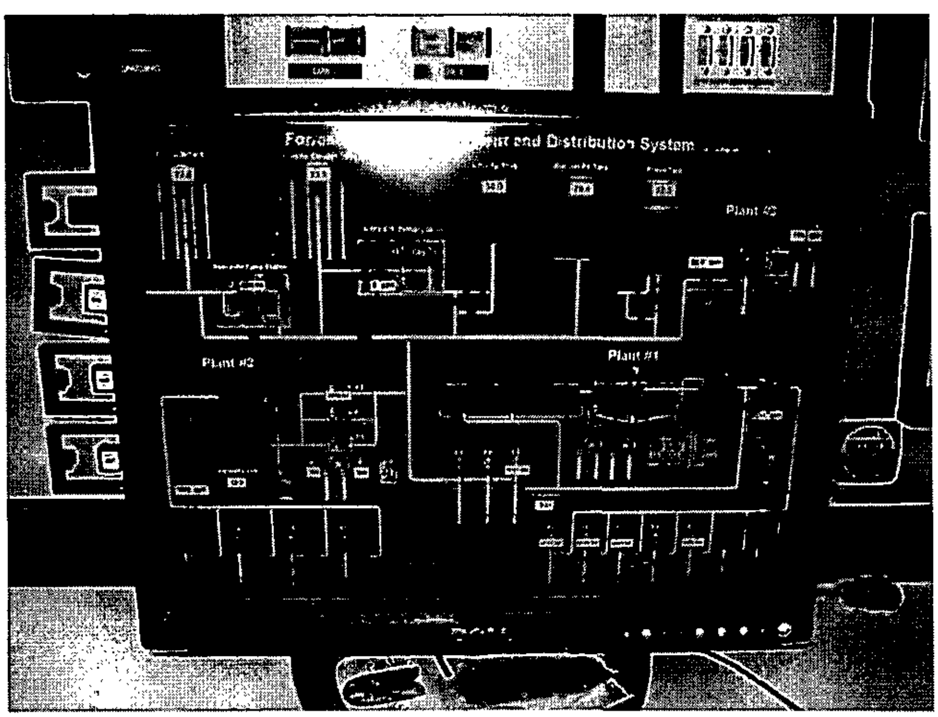

Photo 22: Screenshot of SCADA System

3.6.2 Well Transmission Line and Water Treatment Plant Hydraulics

Groundwater from the wellfield serving WTP #1 is pumped by a vertical turbine pump arrangement located at each of the seven (7) active wells through a common transmission line routed to the plant. The size of the transmission line increases as more wells are combined, eventually becoming an 18-inch line entering the WTP #1 site from the north. Record drawings indicate that a 24-inch raw water influent line is constructed to the influent metering pit, allowing for planned (at the time of design) future wellfield and treatment plant expansion.

The well pumps and transmission line were designed to provide adequate hydraulic head (pressure) to enter the multi-cone aerators. Downstream treatment process components (solids contact unit, recarbonation basin, and filters) are then fed by gravity by the hydraulic head created in the aeration basin following passage through the aerators. Filtered water gravity flows directly into the finished water clearwell located below the filters.

Understanding that any evaluation of potential treatment alternatives for TCE removal/reduction would require a better understanding and determination of the pressure that can be delivered to the influent of the plant, a quick evaluation of the well pump and transmission hydraulics was undertaken during this effort. A procedure for conducting a series of hydraulic test conditions was developed with the Water Utility Staff and City Engineer and the Omaha District Corps of Engineers. This process consisted of a staged approach to turning on (and turning off) successive well pumps and creating artificial head (by incrementally closing valves in the influent metering pit) and measuring both flow and pressure delivered at the influent to the plant. Plant influent flow is measured by a venturi meter located approximately 30 feet upstream of a pressure gauge just upstream of a tee connection to the two existing aerators. This procedure was performed to create a hydraulic capacity curve for the wellfield and the transmission line. Pressure at the valve pit upstream of the existing aerators was recorded for each scenario. The static pressure from the gauge to the top of the aerators overflow is 25.45 feet. A schematic diagram of the piping arrangement is depicted in Figure 1: Schematic of Existing Transmission Line Piping to Aerators.

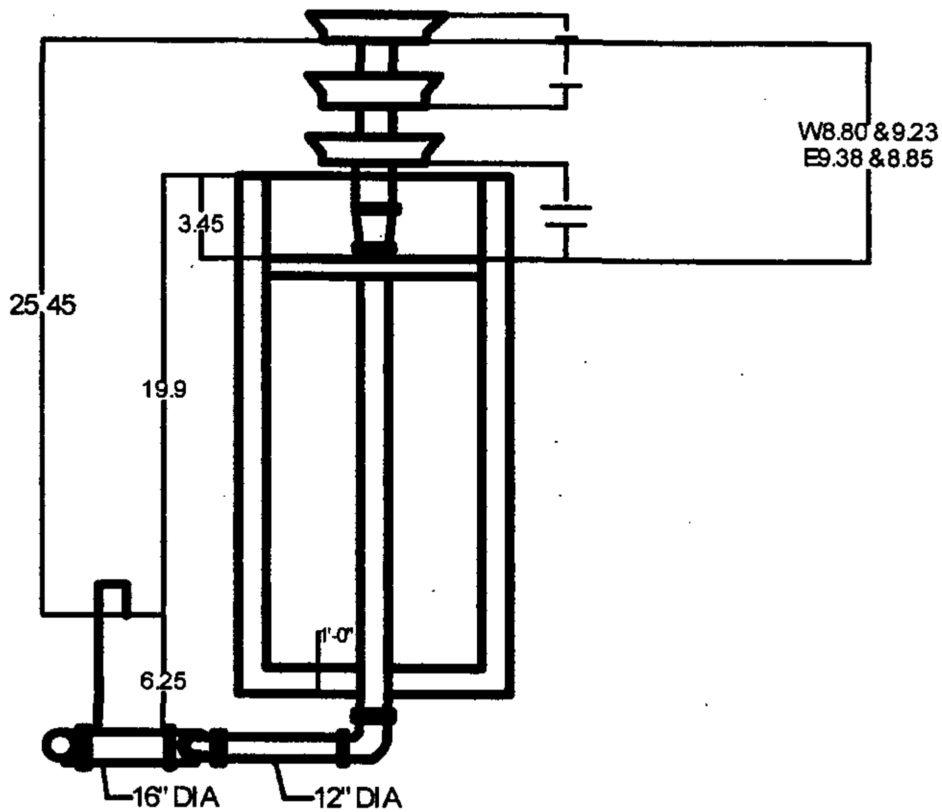

Figure 1: Schematic of Existing Transmission Line Piping to Aerators

The results of this field-collected data are provided in Table 5: Transmission Line Hydraulic Testing Results. These results are graphically illustrated in Figure 2: Water Treatment Plant #1 Transmission Line Hydraulics and Figure 3: Water Treatment Plant #1 Transmission Line Hydraulics (Wells Operated Independently).

This information provides a basis for determining the maximum available head (without providing additional pumping) for potential TCE treatment processes if they were to be located at the headworks of the plant. *As later discussions in this report will address*, this particular location may not be the best location for the technologies recommended if water softening becomes necessary to allow these technologies to function without interference/maintenance issues with scaling due to hardness. Other locations proposed in this report for these TCE treatment technologies potentially provide better adaptation to incorporating the softening process as originally designed, while facilitating the current (non-softening) bypass mode currently implemented.

Valves Turns From Full Closed		33		11	24.75		8.25	16.5		5.5	8.25		2.75
		PSI	FT	GPM	PSI	FT	GPM	PSI	FT	GPM	PSI	FT	GPM
	Well												
Procedure 1	1-7	12.7	29.3	4834	12.9	29.8	4804	15.2	35.1	4656	38.9	89.8	2636
	7	11.2	25.9	748	11.0	25.4	743	11.2	25.9	759	13.8	31.9	728
	7-6	11.8	27.2	1534	11.7	27.0	1532	11.9	27.5	1536	19.2	44.3	1393
	7-5	12.0	27.7	2362	12.0	27.7	2358	12.5	28.9	2345	26.2	60.5	1973
Procedure 2	7-4	12.2	28.2	3175	12.2	28.2	3169	13.2	30.5	3151	32.6	75.3	2374
	7-3	12.4	28.6	3900	12.4	28.6	3909	13.9	32.1	3843	36.2	83.6	2569
	7-3,1	12.5	28.9	4303	12.5	28.9	4321	14.5	33.5	4207	37.0	85.4	2603
	7-1	12.7	29.3	4841	12.9	29.8	4828	15.1	34.9	4696	38.6	89.1	2691
	1		0.0			0.0			0.0			0.0	
	2	11.0	25.4	776	11.0	25.4	774	11.1	25.6	772	12.8	29.6	761
	3	11.1	25.6	880	11.1	25.6	877	11.1	25.6	860	12.8	29.6	851
Procedure 3	4	11.0	25.4	904	11.0	25.4	902	11.2	25.9	871	12.9	29.8	858
	5	11.0	25.4	862	11.1	25.6	860	11.1	25.6	860	12.8	29.6	847
	6	11.1	25.6	838	11.0	25.4	838	11.2	25.9	835	13.0	30.0	818
	7	11.0	25.4	754	11.0	25.4	756	11.1	25.6	761	12.8	29.6	747

NOTE: 1 Foot = 2.309 PSI

Table 5: Transmission Line Hydraulic Testing Results

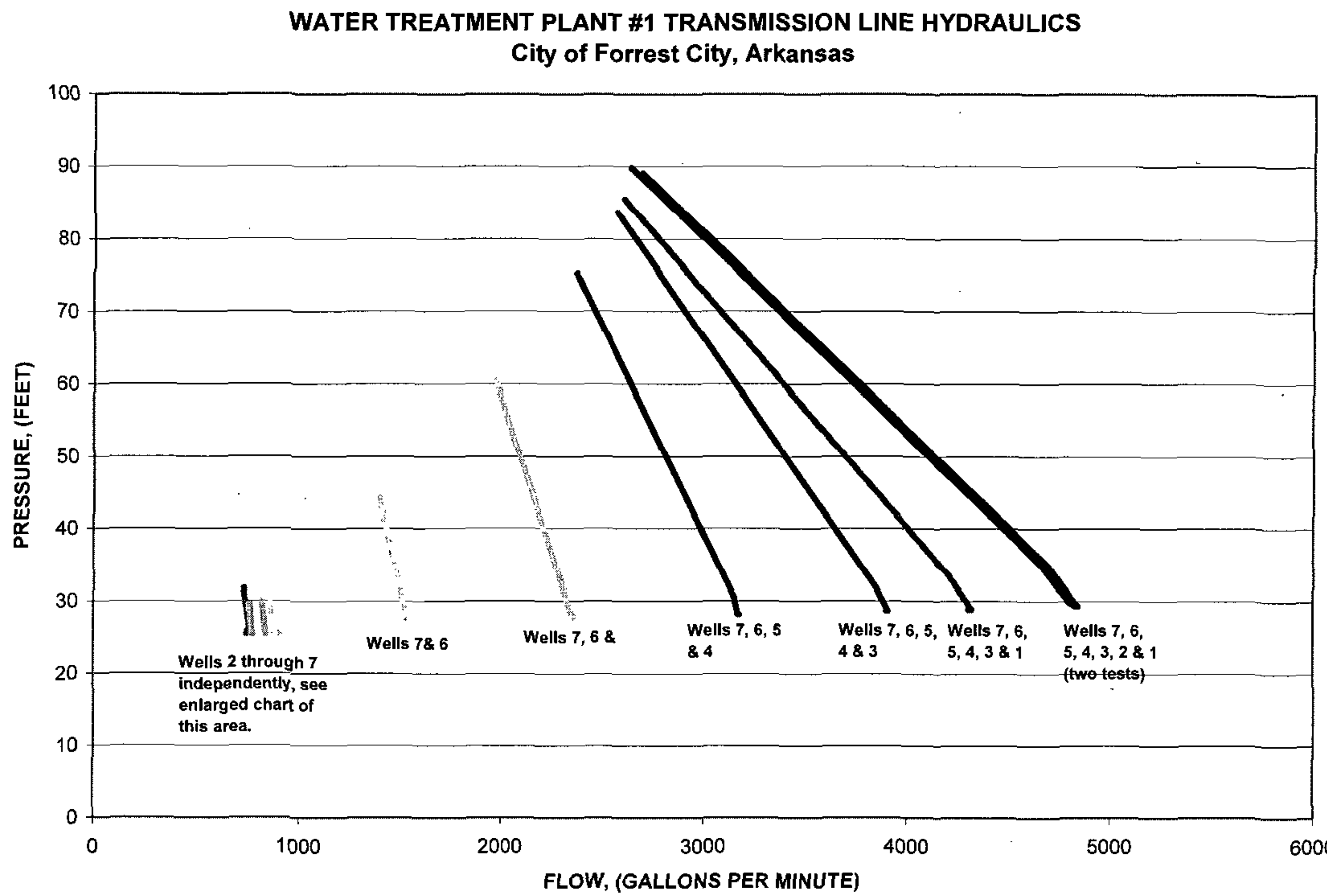

Figure 2: Water Treatment Plant #1 Transmission Line Hydraulics

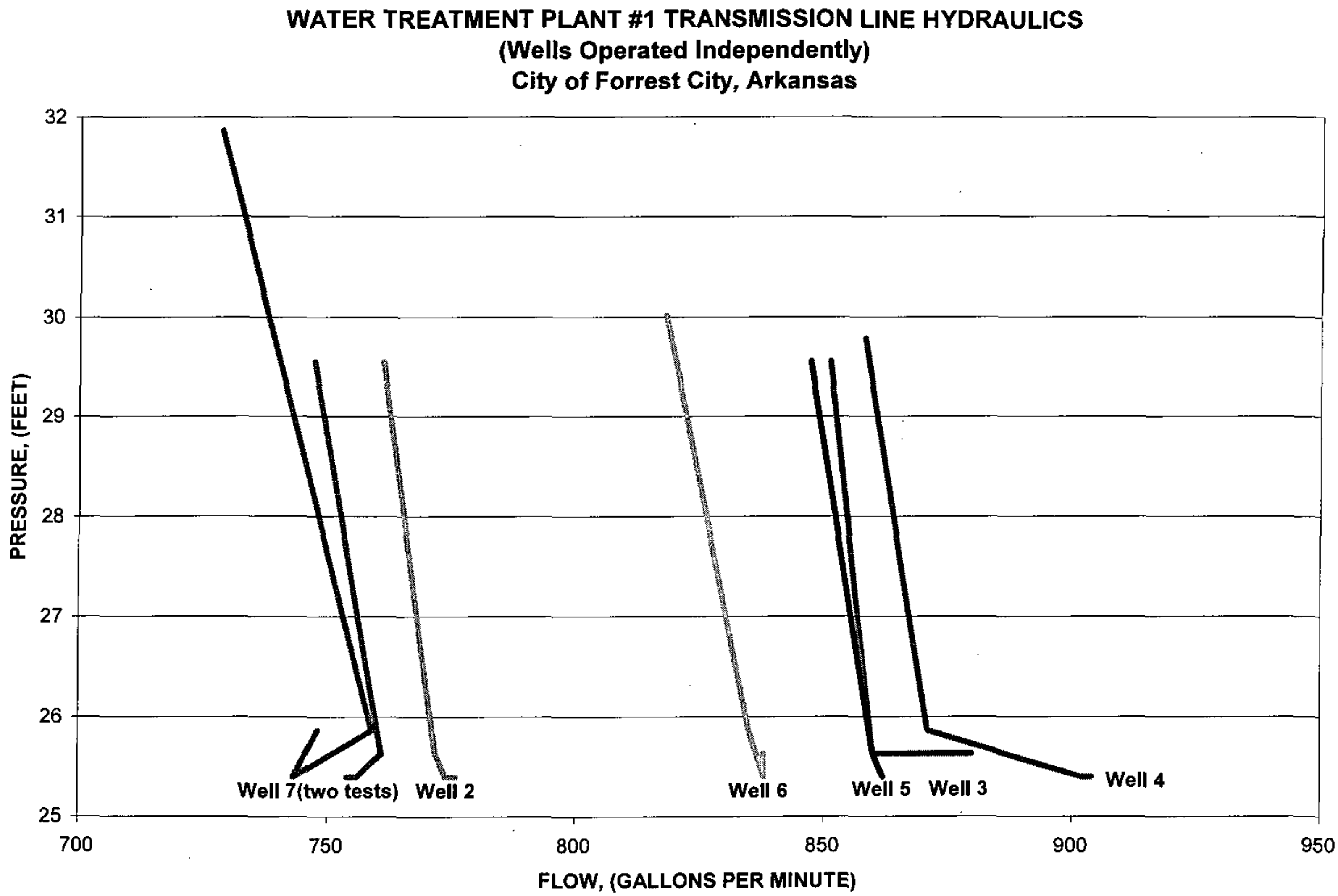

Figure 3: Water Treatment Plant #1 Transmission Line Hydraulics (Wells Operated Independently)

3.6.3 Existing TCE Reduction by WTP #1

Under the current operating mode of WTP #1, the aeration provided by the twin "Multicone" aerators provides some, but marginal, reduction of the TCE concentration of the plant influent. It is difficult to determine what the capability of that system provides in terms of TCE reduction as existing data is not comprehensive enough to establish all the operational parameters and results. Based upon one recent test conducted by the City of Forrest City, with only Well #2 operating, the following results were found:

Table 6: Existing TCE Removal Performance

Location	TCE Concentration (ug/L)
Upstream of Aerators (pre-aeration)	17.89
Post Aeration	8.60
Post Filtration	8.01
Assumed flowrate through plant of 780 gallons per minute (based upon transmission line hydraulic testing results for operating Well #2 independently)	

Under this particular scenario the calculated removal efficiency provided by the existing aerators was 51.9%. This one result should not be considered predictive of performance under any other operating scenario, particularly under increased flowrates or higher TCE influent concentrations.

4 NON TREATMENT ALTERNATIVE

4.1 Wellfield Blending

One potential management approach to dealing with achieving TCE MCL compliance at Water Treatment Plant #1 might include blending of the flows delivered by the wells serving that facility. To date only four (4) of the seven (7) current wells have shown TCE contamination. Under this approach, and under certain demand and pumping conditions, blending wells with no detectable levels of TCE with those with contamination (beginning with those having the lowest contamination) may provide a blended flow that meets MCL requirements. Realizing that there are an infinite number of possible flow demand scenarios and inconsistent TCE concentrations in the wells, this approach can be difficult to manage and likely not applicable in covering the entire water demand range and well operating scenarios. Current plant operation utilizes one variant of this method as only the non-contaminated wells are pumped. This mode of operation is satisfactory when water demands are at or below the capacity delivered by this combination of wells (#4A, #6 and #7).

The following information is a summary of only several of the infinite potential scenarios that could exist in operating the wellfield. These are provided to illustrate the effect of blending well flows (at various flowrates) at various levels of TCE contamination. The predicted values represent the expected blended flow concentration of TCE to the influent of WTP #1, upstream of any treatment process (existing or proposed).

NOTE: It must be noted that these predictions do not consider the hydrogeology impacts and the resulting movement of the contaminant plume that may result from the pumping scenarios evaluated. Groundwater modeling and contaminant plume tracking is a critical component in utilizing this non-treatment method, and as such may significantly impact the success of this option.

Scenario One examined pumping all seven (7) wells each at their design pumping rate and assuming the highest historical TCE concentration measured for each of the four (4) contaminated wells. Results from this scenario indicate that the blended plant influent will be greater than the current MCL for TCE. Therefore for conditions similar to this scenario, treatment will be required to reduce the finished water TCE concentration to meet the MCL. A summary of this scenario is provided in Table 7: Wellfield Blending Scenario One below:

Table 7: Wellfield Blending Scenario One

Well No.	Design Pumping Rate (gpm)	Design Pumping Rate (MGD)	Scenario Flow* (gpm)	Scenario Flow* (MGD)	TCE (ppb)	TCE (mg/L)	TCE Mass (Lbs)	TCE Weighted Mass (ppb*gpm)
W1A	600	0.86	600	0.86	**8.6**	0.0086	0.0620	5160
W2	800	1.15	800	1.15	**54.33**	0.0543	0.5220	43464
W3	800	1.15	800	1.15	**4.93**	0.0049	0.0474	3944
W4A	800	1.15	800	1.15	0	0.0000	0.0000	0
W5	800	1.15	800	1.15	**36**	0.0360	0.3459	28800
W6	800	1.15	800	1.15	0	0.0000	0.0000	0
W7	800	1.15	800	1.15	0	0.0000	0.0000	0
Total Flow	5400	7.78	**5400**	**7.78**			0.9772	81368
Blended TCE					**15.07****			

** Based on Design Pumping Rate- Information dated October 2008 from Forrest City Water Utilities -General Manager*

***Blended TCE concentration based on the total pumping Flow of 7.78 MGD (5400 gpm) prior to the existing Aerators*

Blended WTP#1 Well Field TCE Concentration

=	<u>0.977197133</u>	<u>lbs</u>	<u>81368</u>
	7.78	MG	5400
=	0.125668356	lbs/MG	
=	15.07	ppb	15.07

Scenario Two examined pumping all seven (7) wells, each at their actual pumping rate as determined by the transmission line hydraulic testing, and assuming the highest historical TCE contamination for each of the four (4) contaminated. Results from this scenario also indicate that the blended plant influent will be greater than the current MCL for TCE. Treatment will be required at WTP #1 to reduce the finished water TCE concentration to meet the MCL. A summary of this scenario is provided in Table 7: Wellfield Blending Scenario One below:

Table 8: Wellfield Blending Scenario Two

Well No.	Design Pumping Rate (gpm)	Design Pumping Rate (MGD)	Scenario Flow* (gpm)	Scenario Flow* (MGD)	TCE (ppb)	TCE (mg/L)	TCE Mass (Lbs)	TCE Weighted Mass (ppb*gpm)
W1A	600	0.86	403	0.58	**8.6**	0.0086	0.0416	3465.8
W2	800	1.15	538	0.77	**54.33**	0.0543	0.3510	29229.54
W3	800	1.15	725	1.04	**4.93**	0.0049	0.0429	3574.25
W4A	800	1.15	813	1.17	0	0.0000	0.0000	0
W5	800	1.15	828	1.19	**36**	0.0360	0.3580	29808
W6	800	1.15	786	1.13	0	0.0000	0.0000	0
W7	800	1.15	741	1.07	0	0.0000	0.0000	0
Total Flow	5400	7.78	**4834**	**6.96**			0.7936	66077.59
Blended TCE					**13.67****			

** Based on Hydraulic runs made by Forrest City Water Utilities -dated January 2006*
** Blended TCE concentration based on the total pumping Flow of 6.96 MGD (4834 gpm) prior to the existing Aerators*

Blended WTP#1 Well Field TCE Concentration	=	$\frac{0.793565425}{6.96}$	$\frac{\text{lbs}}{\text{MG}}$	$\frac{66077.59}{4834}$
	=	0.114002296	lbs/MG	
	=	13.67	ppb	13.67

Scenario Three examined assumes pumping all seven (7) wells, each at their actual pumping rate as determined by the transmission line hydraulic testing, and assuming a TCE contamination of 36 ppb for each of the four (4) contaminated wells. This concentration is used because it is the highest concentration of TCE for Well #4A. This well was used because it has been the most consistent in historical TCE concentrations.

Results from this scenario also indicate that the blended plant influent will be greater than the current MCL for TCE. Treatment will be required at WTP #1 to reduce the finished water TCE concentration to meet the MCL. A summary of this scenario is provided in Table 9: Wellfield Blending Scenario Three below:

Table 9: Wellfield Blending Scenario Three

Well No.	Design Pumping Rate (gpm)	Design Pumping Rate (MGD)	Scenario Flow* (gpm)	Scenario Flow* (MGD)	TCE (ppb)	TCE (mg/L)	TCE Mass (Lbs)	TCE Weighted Mass (ppb*gpm)
W1A	600	0.86	403	0.58	**36**	0.0360	0.1742	14508
W2	800	1.15	538	0.77	**36**	0.0360	0.2326	19368
W3	800	1.15	725	1.04	**36**	0.0360	0.3135	26100
W4A	800	1.15	813	1.17	0	0.0000	0.0000	0
W5	800	1.15	828	1.19	**36**	0.0360	0.3580	29808
W6	800	1.15	786	1.13	0	0.0000	0.0000	0
W7	800	1.15	741	1.07	0	0.0000	0.0000	0
Total Flow	5400	7.78	**4834**	**6.96**			1.0783	89784
Blended TCE					**18.57****			

** Based on Hydraulic runs made by Forrest City Water Utilities -General Manager dated January 2006*

*** Blended TCE concentration based on the total pumping Flow of 6.96 MGD (4834 gpm) prior to the existing Aerators*

1. Blended Well Field Flow TCE Concentration

=	1.078269926 / 6.96	lbs / MG	89784 / 4834	ppb*gpm / gpm
=	0.154902474	lbs/MG		
=	18.57	ppb	18.57	ppb

Scenario Four evaluates a blended flow TCE concentration when operating the WTP#1 at the current 5.0 MGD peak flow limited by the existing hydraulics. Under this scenario all non-contaminated wells (#4A, #6 & #7) would be operated at their design flowrate (approximately 2,400 gpm or 3.456 MGD). The remainder of the groundwater (1,072 gpm or 1.544 MGD) would need to be supplied by wells that are contaminated. The management approach would be to pump the greatest flows from the least TCE contaminated wells. For this scenario it was again assumed that all wells would have a TCE concentration of 36 ppb. In that instance no preference would be made to which contaminated wells would be pumped first (they are all equally contaminated).

Results from this scenario also indicate that the blended plant influent will be greater than the current MCL for TCE. Treatment will be required at WTP #1 to reduce the finished water TCE concentration to meet the MCL. A summary of this scenario is provided in Table 10: Wellfield Blending Scenario Four below:

Table 10: Wellfield Blending Scenario Four

Well No.	Design Pumping Rate (gpm)	Design Pumping Rate (MGD)	Scenario Flow* (gpm)	Scenario Flow* (MGD)	TCE (ppb)	TCE (mg/L)	TCE Mass (Lbs)	TCE Weighted Mass (ppb*gpm)
W1A	600	0.86	0	0.00	36	0.0360	0.0000	0
W2	800	1.15	800	1.15	36	0.0360	0.3459	28800
W3	800	1.15	0	0.00	36	0.0360	0.0000	0
W4A	800	1.15	800	1.15	0	0.0000	0.0000	0
W5	800	1.15	275	0.40	36	0.0360	0.1189	9900
W6	800	1.15	800	1.15	0	0.0000	0.0000	0
W7	800	1.15	800	1.15	0	0.0000	0.0000	0
Total Flow	5400	7.78	3475	5.00			0.4648	38700
Blended TCE					11.14**			

** Based on Design Pumping Rate- Information dated October 2008 from Forrest City Water Utilities -General Manager*
** Blended TCE concentration based on the total pumping Flow of5.0 MGD (3475 gpm) prior to the existing Aerators*

1. Blended Well Field Flow TCE Concentration

=	0.464771520 lbs / 5.00 MG		38700 ppb*gpm / 3475 gpm	
=	0.09288	lbs/MG		
=	11.14	ppb	11.14	ppb

Scenario Five evaluates a blended flow TCE concentration when operating the WTP#1 at the current 5.0 MGD peak flow limited by the existing hydraulics, same as for Scenario Four. Scenario Five also assumes pumping all non-contaminated wells (#4A, #6 & #7) at their design flowrate (approximately 2,400 gpm or 3.456 MGD). The remainder of the groundwater (1,072 gpm or 1.544 MGD) would need to be supplied by wells that are contaminated. Unlike for Scenario Four, Scenario Five assumes the highest historical TCE concentration measured for each of the four (4) contaminated wells. Therefore the management approach would be to pump the greatest flows from the least TCE contaminated wells.

Results from this scenario also indicate that the blended plant influent can be less than the current MCL for TCE. Along with Wells #4A, #6 and #7 (uncontaminated) operating at design pumping rate, *Well #3 could be operated at design pumping rate along with* approximately 275 gpm delivered from Well 1A. A summary of this scenario is provided in Table 11: Wellfield Blending Scenario Five below:

Table 11: Wellfield Blending Scenario Five

Well No.	Design Pumping Rate (gpm)	Design Pumping Rate (MGD)	Scenario Flow* (gpm)	Scenario Flow* (MGD)	TCE (ppb)	TCE (mg/L)	TCE Mass (Lbs)	TCE Weighted Mass (ppb*gpm)
W1A	600	0.86	**275**	0.40	**8.6**	0.0086	0.0284	2365
W2	800	1.15	***0***	0.00	**54.33**	0.0543	0.0000	0
W3	800	1.15	**800**	1.15	**4.93**	0.0049	0.0474	3944
W4A	800	1.15	800	1.15	0	0.0000	0.0000	0
W5	800	1.15	**0**	0.00	**36**	0.0360	0.0000	0
W6	800	1.15	800	1.15	0	0.0000	0.0000	0
W7	800	1.15	800	1.15	0	0.0000	0.0000	0
Total Flow	5400	7.78	**3475**	**5.00**			0.0758	6309
Blended TCE					**1.82****			

** Based on Design Pumping Rate- Information dated October 2008 from Forrest City Water Utilities -General Manager*

***Blended TCE concentration based on the total pumping Flow of 5.0 MGD (3475 gpm) prior to the existing Aerators*

1. Blended Well Field Flow TCE Concentration

$$= \frac{0.075768566 \text{ lbs}}{5.00 \text{ MG}} \qquad \frac{6309 \text{ ppb*gpm}}{3475 \text{ gpm}}$$

$$= 0.0151416 \text{ lbs/MG}$$

$$= 1.82 \text{ ppb} \qquad 1.82 \text{ ppb}$$

Scenario Six predicts the maximum theoretical hydraulic delivery that can be produced by the wellfield and delivered to WTP #1 at or below the 5 ppb MCL for TCE. All four (4) contaminated wells were assumed to be at the highest historical TCE contamination. Based upon this analysis, it appears that approximately 5.93 MG could be delivered in a blended flow to WTP #1. This scenario requires maximum pumping of the uncontaminated wells (#4A, #6 and #7) and operating the least contaminated wells #3 and #1A at their design pumping rates. The additional flowrate produced by the next lowest contamination, Well #5, could be up to approximately 320 gallons per minute in order to keep the blended flow at 5.0 ppb or less.

A summary of this scenario is provided in Table 12: Wellfield Blending Scenario Six below:

Table 12: Wellfield Blending Scenario Six

Well No.	Design Pumping Rate (gpm)	Design Pumping Rate (MGD)	Scenario Flow* (GPM)	Scenario Flow* (MGD)	TCE (ppb)	TCE (mg/L)	TCE Mass (Lbs)	TCE Weighted Mass (ppb*gpm)
W1A	600	0.86	**600**	0.86	**8.6**	0.0086	0.0620	5160
W2	800	1.15	**0**	0.00	**54.33**	0.0543	0.0000	0
W3	800	1.15	**800**	1.15	**4.93**	0.0049	0.0474	3944
W4A	800	1.15	800	1.15	0	0.0000	0.0000	0
W5	800	1.15	**319**	0.46	**36**	0.0360	0.1379	11484
W6	800	1.15	800	1.15	0	0.0000	0.0000	0
W7	800	1.15	800	1.15	0	0.0000	0.0000	0
Total Flow	5400	7.78	**4119**	**5.93**			0.2473	20588
Blended TCE					**5.00**			

** Based on Hydraulic runs made by Forrest City Water Utilities -dated January 2006*
** Blended TCE concentration based on the total pumping Flow of 5.96 MGD (4137 gpm) prior to the existing Aerators*

2. Blended WTP#1 Well Field TCE Concentration

= $\frac{0.247253645 \text{ lbs}}{5.93 \text{ MG}}$ $\frac{20588}{4119}$

= 0.041685827 lbs/MG
= 5.00 ppb 5.00

It should be noted that these evaluations have not considered TCE reduction that appears to be provided by the existing WTP #1 aerators. This removal efficiency, based upon data provided by the Water Utility Staff, appears to be approximately 52 percent based upon an influent TCE concentration upstream of the aerators of 17.89 ppb and a post aeration concentration of 8.60 ppb. These results however are based only on Well #2 (approximately 776 gpm) operating at the time. TCE removals provided by the existing multi-cone aerator system are not considered to be predictable at higher influent flowrates.

It is apparent by the previous analysis that under certain groundwater pumping scenarios achieving regulatory compliance with the TCE MCL is possible. The risk in relying on this method is the variable effect that continued pumping of contaminated wells will have on the TCE concentration produced by a given well. This method also may become less reliable over time as the wellfield is pumped. Historical levels have had tremendous swings in concentrations that appear to be related to how long a particular well is operated. Extended operation of a contaminated well has not been performed to predict the long-term concentration trend. It is apparent that resting a well has the effect of providing temporary reductions in TCE concentrations.

In order to implement a management approach of this type it would be imperative that individual flow meters be installed on each well pump as well as an appropriate flow control device. Although flow control is not currently practiced, a valve would provide the simplest method of control. Controlling flowrates with a valve however is not recommended because of the wasted electrical power costs. A variable frequency drive (VFD) installed on the pump motor (integrated into the existing plant control system) would be a much better solution for throttling flow produced at a well. Electrical power is not wasted as the speed of the motor is varied by the VFD to control the pump delivery from the well. More calibrated control of the flowrates can be achieved by varying motor speeds (automatically if incorporated into plant control logic) as compared to inducing headloss through a throttling valve.

Utilizing this method will also reduce the full potential of this supply/treatment system at WTP #1. Maximum flows produced would be limited to meeting an MCL for TCE rather than geological, hydraulic or treatment capacity that may provide additional capacity.

Another important consideration in utilizing this method is the increased analytical costs. Groundwater management would require an appropriate frequency in testing to verify individual well TCE concentrations as well as verifying the blended flow concentrations delivered to the system.

5 TREATMENT ALTERNATIVES & DESIGN PARAMETERS

There are several commonly used unit treatment processes that can be utilized to remove VOCs (volatile organic compounds), including TCE, from groundwater. These include: adsorption, air-stripping, oxidation/biological and reverse osmosis processes. Two treatment processes, carbon adsorption and air-stripping units are considered to be the most viable, suitable and widely accepted for potable water treatment purposes. These two technologies best meet the scale (design flows of the Forrest City system), common acceptance by the public water regulatory community and provide efficient and predictable contaminant removal. Both of these treatment processes have been evaluated for application at the Forrest City Water Treatment Plant #1. The following evaluation consists of the examination of the feasibility of the these processes in consideration of sizing, cost including both construction and long-term operation and maintenance, advantages and disadvantages of the technology and implementation specifically at the City of Forrest City WTP #1. The following design parameters were assumed and used throughout this evaluation:

Design Flowrate to Treatment Process	3,475 gallons per minute (5.0 MGD-based on stated hydraulic capacity of existing WTP #1)
Design Influent TCE Concentration	36 ppb (μg/l) (based upon Well #4A, most consistent historical concentration)
Design Effluent TCE Concentration	5 ppb (μg/l) (current MCL)

5.1 Carbon Adsorption System

5.1.1 <u>General Technology Description</u>

Adsorption, commonly using activated carbon as the adsorbent media, is known to be an effective water treatment process for the removal of volatile organic compounds. The *adsorption process* is a physical surface phenomenon where an adsorbate (the contaminant in this case) is removed from the contaminated solution and held onto the surface of the adsorbent (activated carbon) by various types of chemical and physical forces present. The contaminant(s) to be removed is adsorbed and held onto the surface (and interspatial surfaces or pores) of the solid adsorbent until the adsorbent no longer has the ability to accumulate any additional adsorbate. Granular Activated Carbon (GAC), specifically liquid phase carbon adsorption, is what is most commonly used as an adsorbent due to it higher adsorptive capacity to achieve reduction of certain organic chemicals (semi-volatile and volatile organics) and chlorine compounds from contaminated waters. GAC is an effective adsorbent medium due to its high surface area to volume ratio. Its surface area can range from 300 to 1200 square m^2/g. for typical commercial activated carbon.

Design considerations for this technology depend on a number of factors. These include the physical and chemical properties of the carbon that relate to media performance, the nature and concentration of the contaminant to be removed (as well as others also present) in the influent stream, temperature and pH of the water, design flow rate, desired effluent concentrations and applicable regulatory agency requirements.

The life expectancy or effectiveness of the adsorbent media (GAC) depends upon the adsorptive capacity of the media (quality of the media and its surface area to volume ratio), the influent contaminant concentration of the influent water stream and the length of time the influent stream is resident in the media bed. For a GAC unit, the removal of the organic compound (TCE in this instance) is measured by the *mass transfer zone* and the *breakthrough capacity* of the unit. Therefore, when sizing a GAC unit, consideration is given to the "*mass transfer zone*", which is the carbon bed depth required to reduce the influent stream contaminant concentration to the required effluent stream concentration. The second design factor is the "*breakthrough capacity*", which is the amount of contaminant material adsorbed (adsorbate) as the mass transfer zones moves through the carbon bed and reaches some final concentration level. For typical water treatment applications (where an MCL or treatment goal for an acceptable contaminant level is defined) the term *breakthrough point* is used to define the point at which adsorption is not occurring at an adequate level to reduce the influent contaminant concentration to the desired effluent concentration. This "point" is usually expressed in units of time (days), assuming a constant influent contaminant concentration and influent flowrate through the media. When this point is reached the media is considered "spent" and no longer providing the performance required to achieve the desired effluent quality. The saturation capacity of GAC is achieved when adsorption of the contaminated no longer occurs and the treated effluent contaminant concentration equals the influent concentration.

Typical breakthrough and saturation capacities for GAC media are based upon one contaminant present. Other contaminants present in the influent stream may impact the actual performance of these units as they complete for sites on the carbon surfaces. When designing these units, consideration should be given to the inorganic composition (such as iron, manganese, and calcium salts or precipitates) of the water; since high levels could interfere with the adsorption process. Water hardness also has an impact on the effectiveness of the adsorption process as scaling or lime deposits tend to plug the media and the number of pore sites available on the carbon. Depending on the levels and nature of these other contaminants in the influent stream, pretreatment upstream of the GAC units may be required in the treatment train to avoid issues impacting the performance of the adsorption process.

Another related design consideration when sizing GAC units, is providing for an appropriate contact time in the media bed. The *EBCT* (*empty bed contact time* in minutes) is estimated by the total volume of the activated carbon bed divided by the liquid flow rate through the media. Typically an EBCT contact time of 15 to 20 minutes is normally adequate for drinking water systems. Increasing the contact time (by providing additional media in the treatment vessel) will increase the bed life or service time of the carbon, therefore decreasing the activated carbon usage rate. However, the increase of the EBCT or bed depth at a constant hydraulic application can impact the treatment cost. The capitol cost of the treatment unit may be greater if larger treatment vessels are required to hold the additional GAC media. Offsetting this increase may be a reduction in the operation costs if less frequent spent carbon removal and fresh carbon replacement is required because of the additional media provided.

In some cases, in order to better design, predict and evaluate how long the carbon media will effectively function, a pilot study may be recommended. A pilot study could be easily done by running one unit for a period of time to demonstrate that the chosen carbon type effectively removes the TCE to the desired effluents levels and to verify if additional pretreatment is required at the plant to reach desired levels of quality before treatment continues. Depending upon vendor recommendations, modeling and/or bench scale testing may be performed.

5.1.2 <u>Advantages/Disadvantages</u>

Advantages:

One of the main advantages of carbon adsorption is the simplicity of operation that this process provides and the rapid implementation of these systems. These units are typically constructed of a welded-steel vessel (pressure tank) and look very similar to a common pressure filter tank. However, unlike pressure filters, operational requirements are reduced (i.e. backwashing). Multiple vessel installations are common and standard piping connections easily facilitate operation in parallel or series (or combinations of both) to achieve the required treatment objectives and media service life. There are many commercial entities that can supply the equipment for this technology and who will provide follow-up carbon removal and replacement services.

This technology can be utilized in cold weather climates without enclosing within a building as long as the flow is continuous or frequent enough to avoid freezing. The footprint of the treatment process will depend upon the size and number of the units required. Space between the units is typically not excessive, providing adequate allowance for piping and access to the vessels for carbon removal and replacement operations.

Disadvantages:

Granular activated carbon adsorption systems need to be serviced periodically for general maintenance but more importantly to provide fresh carbon when the carbon media is spent. Carbon removal and replacement (and/or regeneration) in exchange for fresh carbon is an operation and maintenance cost for this type of system that may have a substantial impact on its life-cycle cost and acceptance over other applicable technologies. The cost for disposal of the saturated or "spent" activated carbon can be quite high depending upon the classification of it as a waste. Regeneration of the spent media on-site is rarely economically advantageous because of the cost of the thermal equipment required to destroy the contaminants held on the media surfaces.

Off-site removal is more common for these systems as media vendors typically either dispose or regenerate the media off-site. The cost for off-site removal and handling can vary depending upon the vendor. The cost for removal and off-site handling and ultimate disposition will depend upon whether the spent carbon becomes a listed or regulated hazardous waste under the Resource Conservation and Recovery Act (RCRA). If the spent carbon used at the site is considered a listed hazardous waste or shows RCRA hazardous characteristics, or exceeds the toxicity test levels, the waste disposition costs increase.

Common GAC units operate under a closed vessel pressure condition. As a result, a pressure headloss is created as the flow passes through the media contained in the vessel. This pressure loss, plus any upstream piping/valving headlosses and the pressure required downstream of the process unit, must be provided at the inlet to the GAC unit. If this pressure loss is greater than what the existing system can accept or facilitate, a booster pump may be necessary to provide the additional pressure to pass the water through the carbon adsorbers or an alternate locations be identified for the GAC units in the overall treatment train.

5.1.3 Applicability to the City of Forrest City WTP #1

5.1.3.1 Design Considerations

For this evaluation several GAC vendors were consulted to determine preliminary sizing of a carbon adsorption treatment system that would satisfy the requirements of the City of Forrest City Water Treatment Plant #1 conditions. Based upon the design flow of 5 MGD (3475 gpm), an influent concentration of 36 ppb of TCE and an 5 ppb or less effluent TCE concentration, the required GAC system would likely consist of at least ten (10) liquid phase carbon vessels (plus two (2) extra to serve as an additional train for back-up operations), totaling 12 units. Each vessel would be loaded with 20,000 pounds of virgin grade NSF-approved carbon.

The ten (10) primary vessels would be designed to operate as five (5) parallel trains of two (2) vessels in series. Assuming an equal distribution of the total influent flow (3,475 gpm) each of the five (5) parallel trains would be treating 695 gpm. This arrangement will provide and empty bed contact time (EBCT) of 15.69 minutes.

With two (2) vessels operating in series for each of the five (5) parallel trains, a total of 40,000 lbs (2 vessels at 20,000 lbs per vessel) of GAC media is estimated to have a breakthrough point of 550 days when operating <u>continuously</u> at the 695 gpm split flowrate. This breakthrough point translates to a treated volume capacity of 550,440,000 gallons for each train before the treated effluent would not achieve the 5 ppb MCL. In other words, the total media capacity contained in all of the 10 vessels can treat approximately 550 MG to levels below the MCL. The average carbon usage rate would be approximately 364 lbs per day or 11,060 lbs per month.

Typically the first of the two vessels in series will experience breakthrough first (since it treats the highest concentration of influent). It is estimated that the breakthrough point on the first vessel will be 220 days. While it is not necessary to change out the media at that particular time (as the second vessel in series removes the TCE that the first vessel no longer has the capacity to achieve), most installations implement carbon removal and replacement of fifty percent (50%) of the vessels at approximately mid-cycle of the overall breakthrough point. This procedure provides a more consistent and balanced approach to media replacement rather than mass removal and replacement of the entire system at the end of the total breakthrough point cycle. The average remaining life of the media available is much more uniform and the cash flow costs for media replacement are spread out more evenly. Therefore approximately

100,000 pounds of the 200,000 pounds of GAC would be removed and replaced every 275 to 300 days.

It should be noted that estimates for these operating and media replacement cycles are based upon a constant influent flowrate and influent TCE concentration. Increasing the flowrate or treating a higher concentration of influent TCE will shorten the breakthrough point as the media is exhausted quicker. The opposite is true if the influent flowrate or influent TCE concentration decreases because the media will be exhausted at a slower rate.

The previous discussion also assumes that the effectiveness of the carbon media is not significantly impacted by other constituents in the influent flow stream. As identified previously other chemicals and compounds have an affinity for carbon and may compete with the removal of the TCE. Influent water hardness may also be a factor, however as discussed later the proposed location for the GAC system is downstream of the treatment processes that are available at WTP #1.

5.1.3.2 Location/Logistics

Implementation of GAC treatment for the removal of TCE at the City of Forrest City WTP#1 can be easily accommodated. This process could be inserted into the existing WTP#1 process scheme in more than one location; however the proposed location that provides the most flexibility, least impact to the existing plant and requires less ancillary equipment to support is immediately downstream of the high service (HS) pumps, just prior to entering the water distribution system. This location provides a number of benefits including allowing maximum benefit of the existing WTP#1 unit treatment processes. The GAC unit would be located downstream of all the process equipment. Therefore if pilot scale testing of the GAC is conducted and water softening is required or necessary for carbon adsorption to work efficiently, the existing WTP#1 equipment could be utilized to provide this hardness reduction.

There is a hydraulic pressure loss (in the range of 2 to 15 psi depending on the flowrate and the unit configuration (parallel or series)) as water passes through the media and the height of the vessels is approximately 20 feet. This static head and operating headloss is greater than what the existing hydraulic profile (gravity flow conditions) of the water treatment plant can deliver to insert the GAC units within/between the existing processes. As a result, a pump would be required to incorporate the GAC units anywhere else in the plant flow scheme.

Locating the GAC units just north of the high service pump room (see Photo 23: Proposed Location of GAC Units) is the proposed physical location. Each unit is approximately 10 feet in diameter. Allowing a 5 foot clearance around each tank would require a site that is approximately 40 feet by 100 to 120 feet (providing an allowance for a stand-by pair of vessels). A physical connection to the water line exiting the high service pump room would be proposed to connect to a manifolded influent line to the GAC system. Another connection downstream would be made to accommodate the GAC manifolded effluent line connection to the water main leading to the water distribution system. A valve (normally-closed) between these connections would provide a GAC system by-pass.

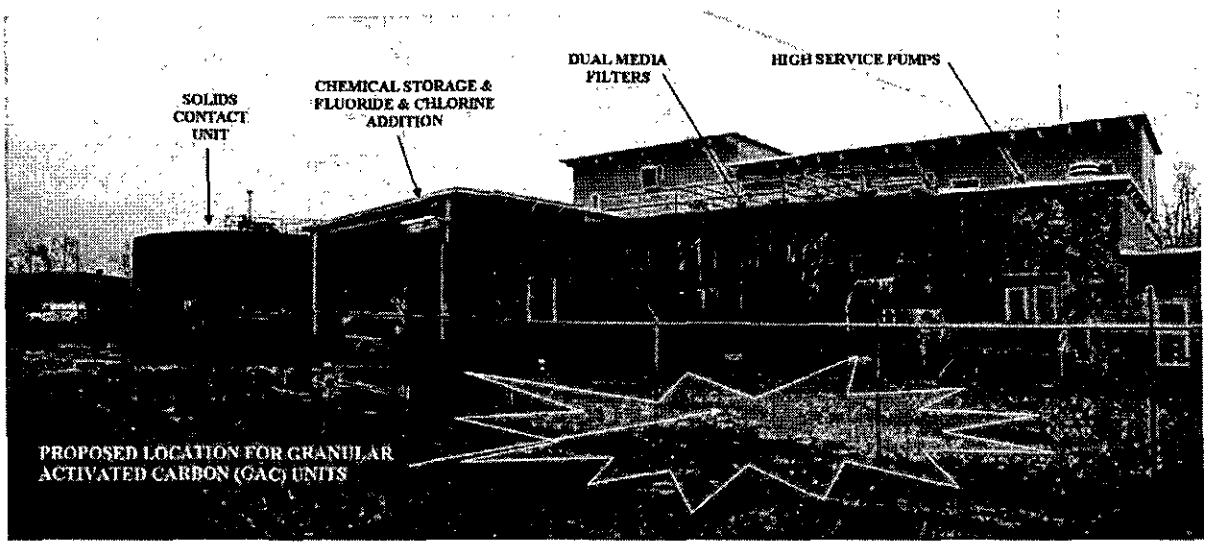

Photo 23: Proposed Location of GAC Units

5.1.4 <u>Cost Evaluation</u>

The following tables provide an opinion of probable cost for Capital Costs and Operation and Maintenance Costs for this alternative. Table 15: Liquid Phase Granular Activated Carbon Present Value Analysis provides a present value analysis for this alternative for comparison to other alternatives presented herein.

Table 13: Liquid Phase Granular Activated Carbon Capital Cost

CAPITAL COST					
ITEM NO.	DESCRIPTION	QUANTITY	UNITS	UNIT PRICE ($)	COST ($)
	Liquid Phase Granular Activated Carbon Adsorption Treatment				
	CONSTRUCTION COSTS:				
1	Granular Activated Carbon System	1	LS	$950,000	$950,000
	Assumption: 12 units total consisting of 6 parallel trains of 2 units in series. Sixth train is considered standby/redundant. Each vessel is filled with 20,000 lbs of NSF 61 virgin grade carbon, vessels range from 10 to 12 feet in diameter, 16 to 18 fee				
2	Freight and Delivery to Jobsite (shipped in pairs)	6	LOADS	$10,000	$60,000
3	On Site Loading/Unloading of Equipment	1	LS	$12,000	$12,000
4	Site Work	1	LS	$25,000	$25,000
5	Security Fencing/Gates	1	LS	$15,000	$15,000
6	Yard Piping - connect to distribution system downstream of high service pumps	1	LS	$20,000	$20,000
7	Treatment Building (40 ft x 120 ft x 14 ft)	4800	SF	$80	$384,000
8	Process Plumbing	1	LS	$25,000	$25,000
9	Electrical Sitework and Interior	1	LS	$50,000	$50,000
10	Electrical Controls: --SCADA System	1	LS	$50,000	$50,000
11	System Start-Up	1	LS	$15,000	$15,000
12	Training	1	LS	$5,000	$5,000
13	Mobilization/Demobilization	1	LS	$20,000	$20,000
	Subtotal-Construction Cost				**$1,631,000**
	Contingencies	25%			$407,800
	Total-Construction Cost				**$2,038,800**
	Professional Services/Indirect Costs:				
	Pre Design Testing/ Pilot Study	1	EA	$20,000	$20,000
	Project Management	6%			$122,300
	Engineering (Design & Construction Phase)	12%			$244,700
	Supervision & Administration/Construction	8%			$163,100
	Total-Professional Services/Indirect Costs				**$550,100**
	Total Opinion of Project Capital Cost				**$2,588,900**

Table 14: Liquid Phase Granular Activated Carbon Operation & Maintenance Cost

OPERATION AND MAINTENANCE COSTS				
DESCRIPTION	**QUANTITY**	**UNITS**	**UNIT PRICE**	**TOTAL**
Liquid Phase Granular Activated Carbon Adsorption Treatment				
ANNUAL OCCURRING COSTS:				
General System Operation and Maintenance:				
Labor Costs: *Assumption:* 2 hrs/day x 365 day/yr	730	HRS	$40	$29,200
System Performance Monitoring/Sampling: *Assumption: 3 samples per process train (upstream and downstream of each vessel)/event x 5 parallel process trains x 1 event/month x 12 months/yr*	180	SAMPLES	$125	$22,500
Miscellaneous Expenses	1	EA	$5,000	$5,000
Subtotal-General System O&M				**$56,700**
GAC Removal, Replacement, Disposal				
Carbon removal and replacement with new virgin material *Assumption: Breakthrough of first vessel is approximately 220 days and second vessel in series is 550 days. Therefore replace one exhausted vessel carbon every 330 days (550-220 days). This is approximately once per year for each of the five (5) operati*	100,000	LBS	$1.60	$160,000
Disposal of Spent Carbon: *Assumption: Following removal and replacement schedule, assuming non-hazardous classification and a spent carbon profile form being approved by a regeneration facility*	100,000	LBS	$0.50	$50,000
Subtotal-GAC Removal, Replacement, Disposal				**$210,000**
Total-Annual Occurring Costs				**$266,700**
NON-ANNUAL OCCURRING COSTS:				
	Project Years	Cost		
Tank Coating & Repairs *Assumption: Tank vessel interior and exterior recoating for 12 vessels @ $5,000 per vessel*	10, 20	$60,000		

Table 15: Liquid Phase Granular Activated Carbon Present Value Analysis

PRESENT VALUE ANALYSIS				
DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	TOTAL
Liquid Phase Granular Activated Carbon Adsorption Treatment				
Total Project Cost Summary O&M Costs:				
Assumptions:				
Project Life	*20*	*yrs*		
Discount Rate	*3%*			
		Cash Flow	**Annuity**	**Present Value**
Project Capital Cost		$2,588,900		$2,588,900
Annual Occurring O&M Costs			$266,700	$3,967,823
Non-Annual Occuring O&M Costs:				
Year	10	$60,000		$44,646
Year	20	$60,000		$33,221
Total Present Value of Project				**$6,634,589**

5.2 *Air Stripping*

5.2.1 General Technology Description

Air stripping and aeration systems are also widely used in water treatment for the removal of volatile organic compounds (VOC's), ammonia (NH3), carbon dioxide (CO^2), hydrogen sulfide (H_2S) and radon from drinking water. The basis for the air stripping process is the mass transfer of dissolved VOC's in water from the liquid phase to the vapor (gas/air) phase. Air strippers remove VOC's from liquid (water) by providing contact between the contaminated liquid and a gas (air). The contaminant is "stripped" from the liquid and converted to a vapor phase component in the gas (air). The contaminant (in the vapor phase) is then typically released to the atmosphere (or may be removed by off-gas treatment systems, typically vapor phase carbon adsorption units). Air quality standards and Regulatory permitting requirements dictate the appropriate release or treatment requirements for the off-gas generated by the air strippers.

The ease and efficiency of the mass transfer of the contaminant to be removed (VOC's) to the vapor phase is dependent upon the *Henry's law constant* for the contaminant to be removed. At equilibrium, the partial pressure of a gas above a liquid is directly proportional to the mole fraction of the gas dissolved in the liquid. This proportionality is known as the *Henry's law constant*. The value of the *Henry's law constant* (H) is an important part in determining whether the contaminant is amenable to stripping and impacts the process design and operating parameters for air strippers. Temperature and the presence of other contaminants (including inorganic components) in the water to be treated impact the value of the Henry's constant.

Air stripping is effective only for water contaminated with VOC or semi-volatile concentrations with a Henry's constant greater than 100 atm. The higher the Henry's Law constant, the more likely substances will volatize rather than remaining in water. Compounds with low volatility at ambient temperature may require preheating of the groundwater.

An important process design consideration for air strippers is the ratio of the volumetric air flow to the volumetric water flow (*A/W*). This is referred as the "*air to water ratio*" (i.e., CFM air to CFM water). The optimum value of the air to water ratio varies for different VOC's (based upon their respective Henry's constant) as well as the influent concentration and expected or desired effluent concentration following stripping.

Air strippers transfer contaminants from one medium to another (liquid to gas) and therefore there is no destruction of the contaminant. Consequently, consideration must be given to the off-gas generated by this technology. Typically the mass of the contaminant stripped and discharged from the unit does not pose a health risk or require further treatment to remove it from the air stream. In that instance the off-gas is discharged directly to the atmosphere. However each situation does require analysis to confirm this condition and proper compliance and coordination with appropriate regulatory air permitting requirements. Off-gas treatment can be incorporated if the mass removed is sufficient enough to require it. Off-gas treatment can be provided by several methods, most commonly it is provided by vapor phase carbon adsorption.

Operating concerns for air strippers include pretreatment or periodic column cleaning required because of the presence of other contaminants in the influent water including inorganic compounds (including calcium hardness, iron and manganese). Other contaminants that may be produced in the stripper if not properly maintained include algae, fungi, bacteria, or fine particles deposition. The air stripping process also requires a substantial amount of power to operate. Power is required primarily for the aeration equipment (blowers) and may be required for influent and effluent pumping from the unit depending upon its location in the overall treatment process.

5.2.2 Air Stripping Type Alternatives

There are several types of air stripping systems available. These generally are differentiated by the presence or non-presence of a packing media material, the method of providing the aeration and the relationship of the liquid flow to the air flow.

Packing media material is provided in some stripper designs to enhance the surface area available for contact between the liquid and the air flow resulting in a smaller process unit volume. This media is typically a manufactured product designed specifically for this purpose.

The method for providing the aeration or air flow through the stripper is generally either referred to as a "forced" draft or an "induced draft" style system. The primary distinction is where the blower unit is located with respect to the stripper unit. Blower units for "forced draft" systems are located upstream of the media (or sieve trays). The blower forces air under pressure through the stripper. Conversely, "induced draft" style units locate the blower on the exhaust side of the stripper to induce (draw or pull) air flow through the stripper.

The relationship of liquid flow to air flow in an air stripper is predominantly either countercurrent, where the liquid flow and air flow are opposite to each other, or co-current where the liquid flow and air flow are in the same direction.

Two of the most common air stripper design styles used for water treatment are the Packed Column and the Sieve Tray. Either of these styles can be applicable to the Forrest City

WTP. A discussion of both styles is presented in the following including design and operational/maintenance considerations with regard to the selection of the most appropriate style.

5.2.2.1 Packed Column Air Stripper

Packed column (or tower) air strippers typically are constructed of a vertical cylindrical column containing an engineered packing media. A liquid distributor or spray nozzle is located above the media for introduction of the contaminated water to the unit. An air distributor is located below the media to facilitate introduction of the air flow to the unit. Contaminated water, pumped to and introduced at the top of the unit, generally flows downward by gravity through the packing media, while at the same time air is introduced at the bottom of the column and flows upward through the media (counter-current flow). The purpose for the packing media is to provide a larger surface area and contact time for the air/liquid contact to occur. This facilitates the transfer of VOC's from the liquid to gas phase.

Treated water exits the bottom of the stripper while the exhaust air (off-gas) containing the volatized materials exits the top of the unit. Off-gas is either directly released to the atmosphere for natural dissipation/natural degradation or further treated for removal in the vapor phase. Off-gas treatment requirements are predicated upon regulatory requirements as previously discussed.

The air flow in a packed column stripper can be introduced in several ways. The most common application is the counter-current method however other methods can be utilized. In a *cross-flow system* the air flows across the tower packing at a 90 degree angle to the direction of the water flow. In the *cascade system*, air is introduced at various points along the tower and flows countercurrent to the water flow. These two alternative systems can provide larger airflow rates at lower gas pressure drops, thus providing a greater driving force for stripping making it more efficient to remove contaminants with lower volatility. These variants are used when very high air-to-liquid ratios are required to remove semi- and low-volatility contaminants from water.

Auxiliary equipment for packed column strippers may include an air heater to improve removal efficiency, any necessary air emission treatment system, and various cleaning systems designed to improve the effectiveness of periodic stripper cleaning.

5.2.2.2 Low-profile sieve tray column or low profile

The sieve tray or low-profile tray air strippers operate similarly to the counter-current packed column air stripper. The primary difference is that no packing media is used. Rather than providing media for extending the surface area for liquid/air contact, a series of perforated trays are stacked vertically to provide this area. Water flows across these trays as air is introduced through the small holes perforated at the bottom of the trays. Water depth across each tray is controlled by a weir at the end of the tray. Water exits over the weir of one tray through a downcomer to the next lower tray. Water continues to flow downward from one tray to the next, tray by tray, as the air flow continues to be bubbled through the perforations. The volatilization occurs as the air contacts the flowing liquid. Water exiting the bottom tray is discharged to the stripper sump below.

Many tray stripper designs include a clear visual side panel for monitoring performance and tray conditions as well as easy access for tray removal for cleaning. As with packed column strippers auxiliary equipment can be provided (air heaters and off-gas treatment).

5.2.3 Advantages/Disadvantages

Advantages:

Air stripper systems, regardless of the type or style of the stripper selected, can be designed to be effective in removing 95-99% of most VOC contaminants over a wide variety of flowrates and influent concentrations. These units are considered a common technology in providing this treatment for potable water systems. Air strippers, unlike carbon adsorption systems, do not generate a waste product requiring further handling/recycling or disposal (unless an off-gas vapor phase carbon adsorption system is required). These systems are relatively easy to operate and maintain if fouling or interference from other inorganic compounds can be controlled or reduced. Mechanical support equipment for these systems includes the aeration source (blower) and any necessary water pumping necessary on the influent or effluent side of the process to incorporate it into the remaining/existing water treatment process.

Air strippers can be designed and installed in multiple vessel parallel treatment units. Some of the more common larger individual units can be supplied in capacities of up to 1,000 gallons per minute. Vendor sources for supplying this process technology are also numerous.

The footprint of the process units is relatively small and will vary depending upon the style of the stripper selected. Packed column strippers typically require the smallest footprint as the column height can be increased to accommodate larger flowrates and/or influent concentrations. Tray strippers are also stacked to accommodate larger flowrates and/or influent concentrations; however the common base footprint is typically larger than for packed columns because the maximum height is typically less to accommodate access for maintenance and cleaning.

Disadvantages:

Air stripper systems are commonly housed within a building or enclosure, particularly when constructed and operated in cold climates. This is predominantly the case for the tray style strippers than for the packed column systems, however special provisions can be incorporated to avoid or minimize the potential for freezing. The other consideration to factor into the appropriate housing is the range of temperatures of the air source supply. Air stripping efficiency is diminished by the temperature of the incoming air temperature. Therefore the cost of implementing this process technology can be inflated by the level of provisions deemed necessary to support cold season operation.

The cost of operating an air stripper system is predominantly based upon the energy cost of power to supply the aeration system (blowers). Additional consideration must be given to the effort that will be necessary to periodically clean any scaling or fouling that may occur on the media in a packed column system or on the trays of a tray style stripper. The greater the presence of calcium hardness, iron or manganese in the influent, the greater the effort and frequency of periodic cleaning will be necessary.

Packed Column versus Low Profile Tray Stripper:

These air strippers can operate over a wide range of air flow rates. So if the water flow rate to the stripper decreases, then the air flow can be decreased. The ratio of air to water flow is lower for a packed tower stripper than for the low profile tray stripper. Therefore, the packed tower will have a smaller cross-sectional area as compared to the low profile stripper for the same treatment conditions. The efficiency of the packed column stripper increases as the packing height increases. Since the pressure drop through the packing media is relatively low, a smaller blower and motor can be used versus that for the same capacity tray stripper. The expected electrical operating cost for the packed column stripper would therefore be less than for a tray stripper. Although packed column units are narrow, typically the columns are tall, ranging from about 15 to 40 feet high. This height, as well as the hydraulic head necessary to deliver the influent water to the top of the column, can present concerns with regard to siting these units or present the need for additional pumping. Packed column strippers are also more difficult to provide periodic cleaning because of the limited access to the media and the depth (height of the tower) of the media bed. If the media cannot be adequately cleaned, the fouling buildup remaining can reduce the air flow rate through the system, making the packing less efficient. This increases the cost to operate and maintain. Chemical solutions may be used to assist in cleaning the packing; otherwise the media must be removed and cleaned outside of the column.

Low–profile tray strippers, as compared to packed column strippers, are smaller and more compact units. Larger units provide additional treatment capacity by increasing the number of trays stacked vertically. The maximum total height is typically less than 12 feet, allowing easier access to the trays for disassembly in providing periodic cleaning. Since no media is used, cleaning is required occasionally on the trays only to ensure that the perforations remain unplugged and that fouling or encrustation of the trays is removed. Low profile tray air strippers however require significantly more air flow rate than the conventional packed tower for the same VOC removal conditions. Due to the high air flow rate and high pressure drop through a low profile unit, a larger blower and motor is used, increasing the overall electrical operating cost for these units..

While the conventional packed columns can operate over a wide range of water flows, low profile air stripper units are commonly limited to water flow rates of less than 1,000 gpm. Depending upon the design flowrate, multiple units may be required to operate in parallel to provide the required capacity. Multiple unit installations however provide better operating and redundancy benefits.

Low profile tray strippers require a greater surface area for siting considerations, but offer the trade-off benefit of lower finished height installations (less than 12 feet unit process height). This potentially allows for more convenient location hydraulically in the treatment process that could eliminate additional influent or effluent pumping considerations.

5.2.4 Applicability to City of Forrest City WTP #1

5.2.4.1 Design Considerations

The air stripping process technology is very applicable for providing the treatment requirements necessary at the City of Forrest City WTP. The hydraulic design capacity requirement of 5 MGD (3475 gpm) and the treatment performance requirement of reducing a design influent concentration of 36.0 ppb, TCE down to an MCL level of less than 5 ppb in the treated effluent stream are well within the capabilities of this process technology. Both variations of this technology, packed column and low-profile tray strippers, are considered applicable to the City of Forrest City installation and are examined in the following evaluation.

For this evaluation several potential air stripper vendors were consulted to determine preliminary sizing, configurations and costing information applicable to the City of Forrest City.

These vendors represent a small sample of potential companies engaged in the design and manufacturer of air strippers, and as such should not be considered an endorsement of any particular manufacturer. Preliminary design evaluation and cost estimates for both types of air strippers, packed column and low-profile sieve tray, are provided in the information that follows. This analysis is based upon a design flow of 5 MGD (3475 gpm), a design influent concentration of 36.0 ppb, TCE, an assumed influent temperature of 50 degrees F and a treated effluent TCE concentration down to or below the MCL level of 5 ppb.

The following discussion assumes that pre-treatment, hardness reduction or special chemical cleaning systems are not necessary to use air strippers for TCE treatment at the City of Forrest City Water Treatment Plant. These may become necessary, based upon further water analysis or pilot-scale testing, in order to make the air stripper systems less prone to fouling or require less-frequent cleaning intervals. It is anticipated, based upon available water quality information (presented previously), that the influent stream will be acceptable for using an air stripper system without providing these additional considerations. Iron, manganese, TDS and TSS are relatively low at the Forrest City WTP. Current hardness levels are considered borderline but low enough not to cause a significant concern for application of the technology.

Another consideration that could impact the air stripper design and cost is the appropriate handling of the off-gas generated. It is anticipated that the off-gas mass generated will not require further treatment in the vapor phase (by vapor phase carbon adsorption or thermal destruction/oxidation) and can be directly discharged to the atmosphere. A more detailed analysis of the total expected mass to be produced should be performed to determine the appropriate treatment and/or permitting action required to comply with regulatory agency requirements.

Packed Column Air Stripper –This alternative would consist of two air stripper units; the second unit would be considered a redundant back-up unit. The units would be designed to operate in parallel; each unit would be capable of treating the total design flow of 3475 gpm (5 MGD). This arrangement will provide flexibility during operation to alternate units during any down time (periodic cleaning or otherwise) without affecting the treatment process. A forced draft blower would be provided to create the airflow. Typically the column of these air stripper units is constructed of aluminum, stainless steel or a fiberglass reinforced plastic (FRP) material. The aerator column geometry dimensions and the packing media material for the air stripper varies depending upon the packed-column air stripper vendor. The City of Forrest City WTP site does not appear to be a limiting factor in selection or siting of this style of stripper system. Two packed column air stripper geometry configurations are considered.

The first configuration is a pair (2 units total) of pre-engineered/manufactured aluminum forced draft air stripping system built of non-circular (rectangular or square) geometry. The unit examined is a 12 feet by 12 feet (nominal) square structure with a height to the influent piping of 16 feet-9 inches (16'-9"). A bed depth of approximately 10 feet of packing media (Jaeger Tri-Pack #2) would be provided in each unit, providing approximately 85-90% reduction in the TCE concentration. Air would be supplied in a forced draft configuration via a 5.0 HP blower. The blower housing and collector pan is supported by four legs. An illustration of this unit is provided in Figure 4: Packed Column Air Stripper (Square Footprint).

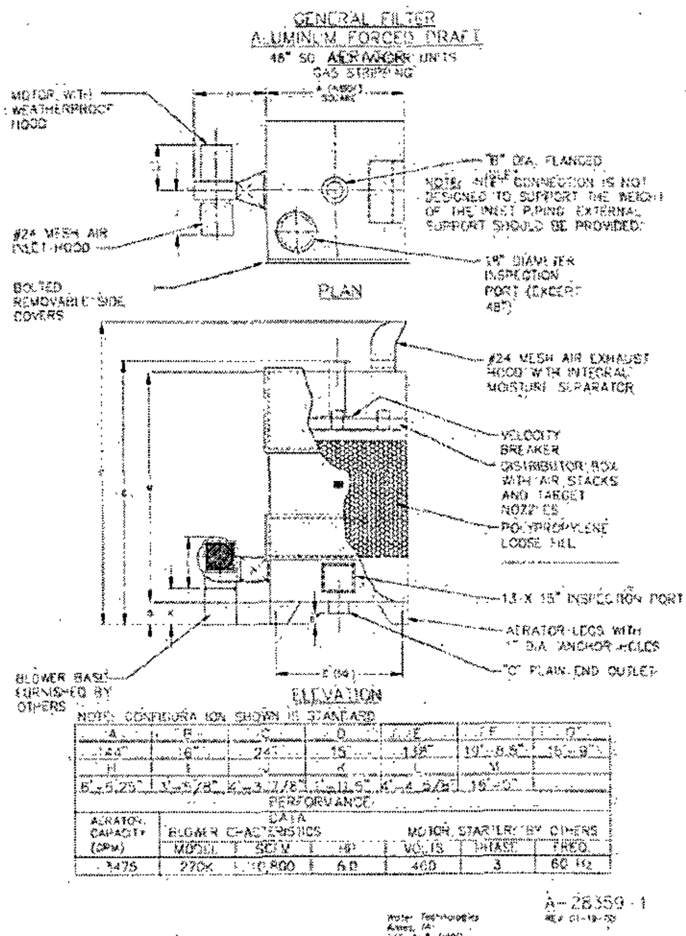

Figure 4: Packed Column Air Stripper (Square Footprint)

The second configuration is a pair (2 units total) of cylindrically-shaped packed column air strippers with forced draft aeration. The column would be 138 inches (11'-6") in diameter and constructed of NSF-approved FRP. The unit would have an overall height of 23'-9" with a water inlet height of approximately 20'-3". Each column would contain a 12 feet deep bed of packing media material (Delta-Pak). The efficiency for this type of system is rated about 88% for removal of TCE. Air is supplied to the column via a 20 Hp blower motor. A sump is located below the column for treated water discharge. An illustration of this unit is provided in Figure 5: Packed Column Air Stripper (Cylindrical Column).

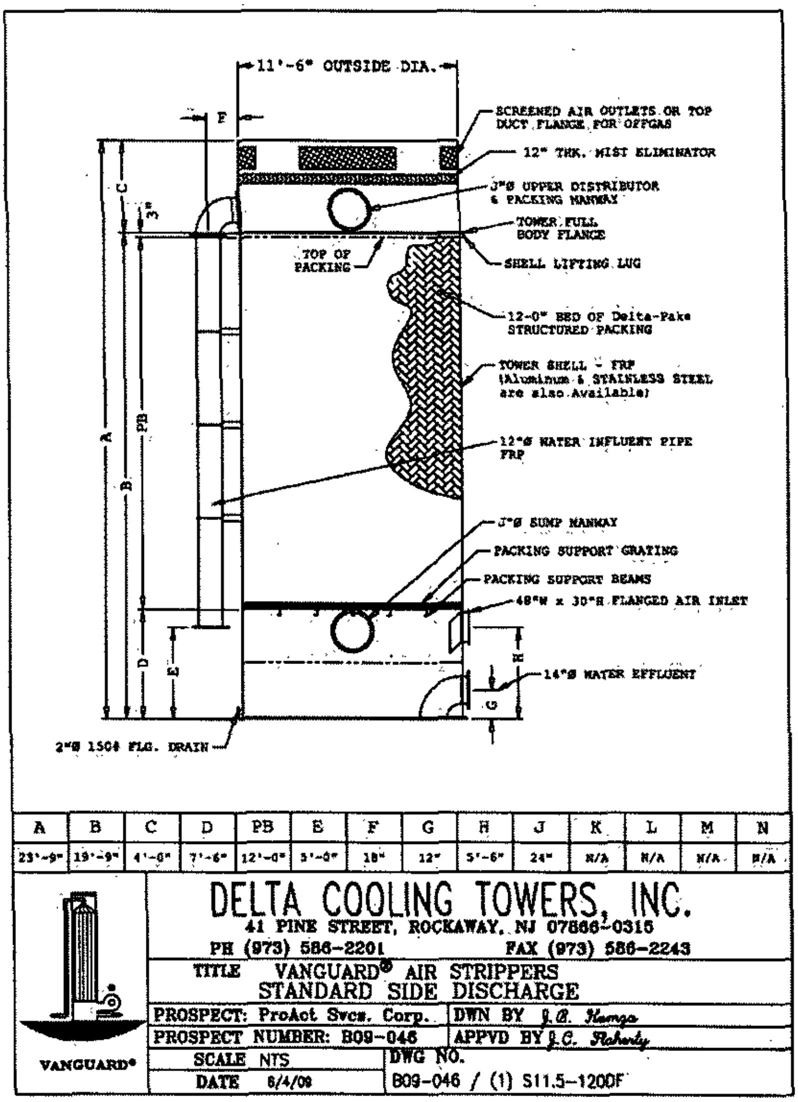

Figure 5: Packed Column Air Stripper (Cylindrical Column)

Low-Profile Sieve Tray Air Stripper – For this alternative, the air stripper considered is a forced draft low-profile sieve tray air stripper unit. This alternative would likely consist of at least four (4) low-profile sieve tray air strippers. In this evaluation a fifth, totally redundant unit, is not considered. Since multiple units are proposed, providing full treatment (albeit at a reduced total flowrate) is possible with one unit out of service. A fifth unit, if required by applicable redundancy criteria, would provide a backup unit without reducing the maximum design flowrate during a temporary interruption in service of any one unit.

For the system examined each stripper unit is rectangular in shape approximately 12'-4" by 6'-5" and constructed entirely of 304 stainless steel. The overall height of the unit is approximately 10'-10" designed for the full rated capacity of 1,000 gpm (using 7 trays), which is also approximately the height of the influent piping at that capacity. The four units would be piped to operate in parallel. Assuming an equal distribution of the total influent flow (3,475 gpm); each unit would hydraulically treat a flow of approximately 869 gpm. At that flowrate and the influent TCE concentration of 36 ppb, only three (3) aeration trays would be required in each stripper to be supplied at the City of Forrest City, providing an overall TCE removal efficiency of 89.4 % (3.8 ppb effluent concentration). This reduces the height of the stripper by 4 trays (each measuring 12.25" in height). Therefore the overall height for the units proposed for the City of Forrest City WTP would be approximately 5'-10". Each low profile air stripper unit is equipped with a 40 HP blower providing an airflow rate of 3, 500 cfm. An illustration of this unit is provided in.Figure 6: Low-Profile Sieve Tray Air Stripper

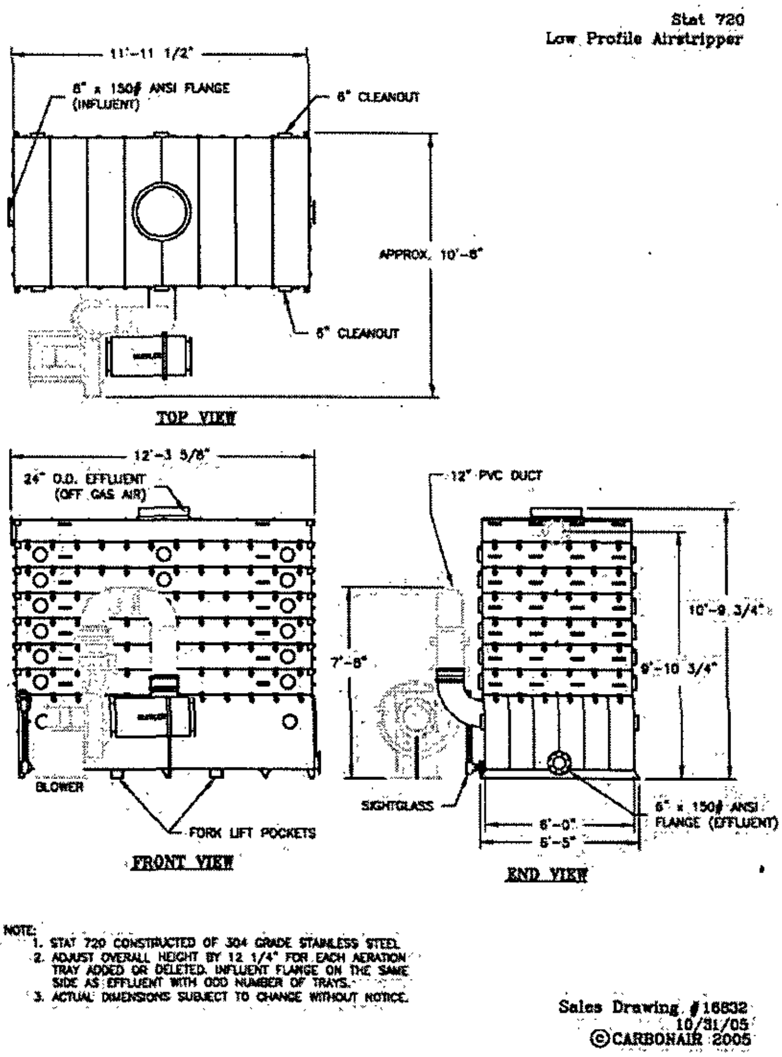

Figure 6: Low-Profile Sieve Tray Air Stripper

5.2.4.2 Location/Logistics

Implementation of air strippers for removal of TCE at the City of Forrest City WTP #1 can be easily accommodated into the existing treatment process. The primary objectives for proper placement of the strippers are to locate them hydraulically in the existing plant hydraulic profile to eliminate the need for pumping to or from the units, and to locate them in an appropriate location that will not jeopardize the potential for future use of the process equipment in the existing plant.

Based upon the hydraulic analysis performed on the transmission line to the plant and delivery at the existing plant aerators, it would appear that both the packed column and the tray strippers could be accommodated. For the packed column stripper in particular (because of its influent piping height) the location would need to be at the head of the plant (at or just upstream of the existing cone aerators). The uppermost discharge from the existing cone aerators is 25.45 feet above the pressure gage located in the plant influent meter pit. The influent piping height of the particular packed column stripper examined is 20'-3" which can be accommodated. The low-profile sieve tray units examined require a much shorter height (less than 6 feet) which allows this style to be located much further down the existing treatment process that at the head of the plant.

Since the discharge of all the air strippers is near the base of the units, without pumping the treated discharge, there is little or no pressure head left to drive the flow through any subsequent existing treatment units at the plant upstream of the finished water clearwell. Discharge from both stripper styles would therefore need to be directly into the existing clearwell. Because of this condition the usefulness of the packed column stripper style is limited without providing discharge pumping if consideration is given to ever using the existing WTP#1 process equipment. It appears that a low-profile tray stripper, because of its much lower influent piping height, provides the best choice when considering the ability to incorporate it into the original plant treatment process without providing a discharge pump from the stripper. While maintaining the full design capabilities of the existing plant, incorporating the air stripper downstream of the softening unit and sand filters also provides a direct benefit to the operation of the air stripper (preventing scaling on the trays) if the softening process is ever brought back on-line.

The proposed location for a low-profile tray stripper (and appropriate building) would be just south of the existing clearwell (see Photo 24: Proposed Location of Air Stripper TCE Removal Units). The most convenient hydraulic connection could be made on the existing 30" filter influent pipe at the connections for piping that were made to allow direct discharge from this influent pipe into the clearwell when the filtration process was discontinued. Effluent discharge from the stripper would be piped directly to the finished clearwell. If filtration is resumed, the stripper influent piping could be connected just below the plant operating floor where the filters were originally designed to discharge into the clearwell.

The size of the building for the air stripper system will depend on the stripper module size. Assuming a pair of packed column air strippers as examined, approximately 12 feet in diameter (if cylindrical) or 12 feet square (if square) and allowing a 5 foot clearance around each unit would require a building of approximately 40 feet by 20 feet. For a shallow tray air stripper system as examined, with each unit approximately 12 feet long and 12 foot wide (including the blower) and allowing a 5 foot clearance around each unit would require a building of approximately 80 feet by 25 feet.

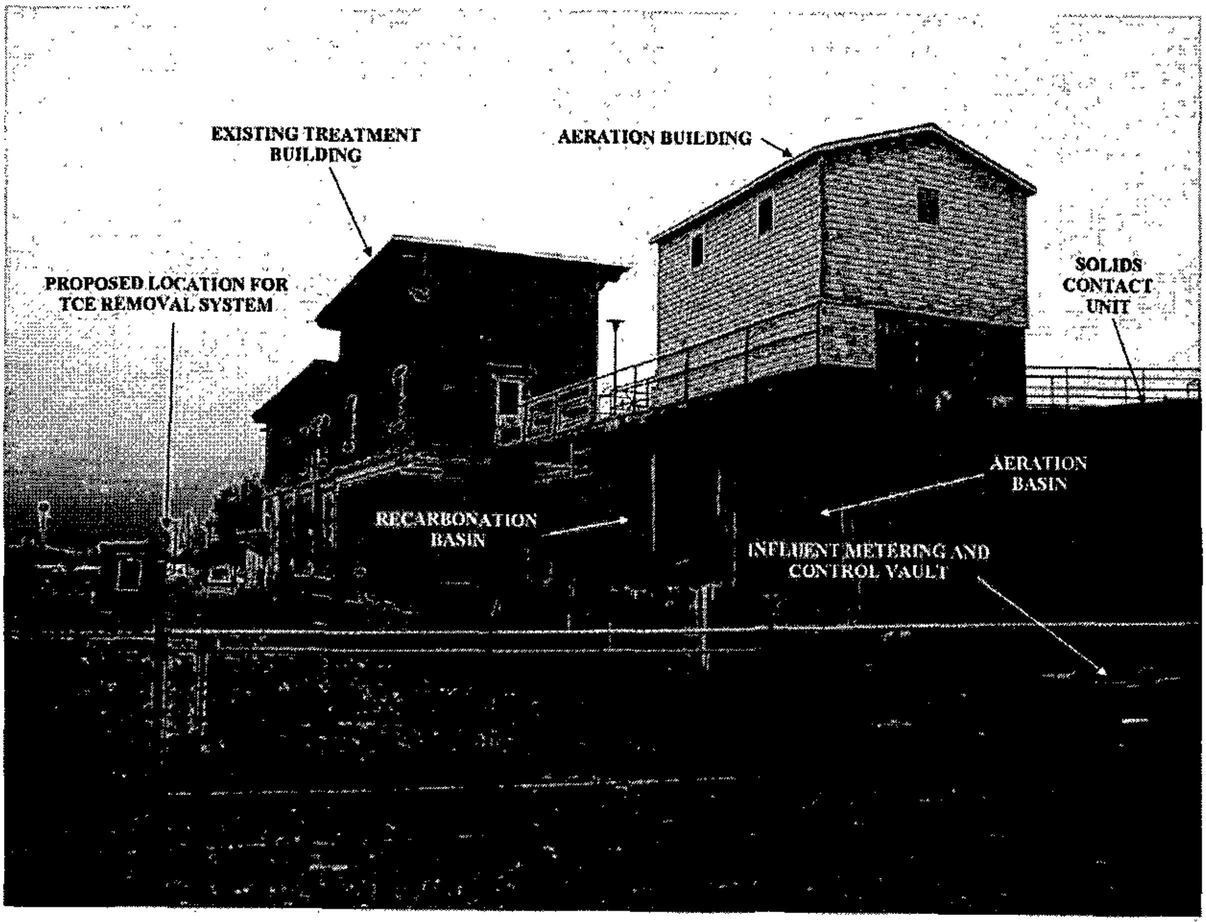

Photo 24: Proposed Location of Air Stripper TCE Removal Units

5.2.4.3 Cost Evaluation

The following tables provide an opinion of probable cost for Capital Costs and Operation and Maintenance Costs for air stripper alternatives. These are provided for both geometry styles of packed column strippers (square and column) and for the low-profile sieve tray stripper. Tables following each of these options provide a present value analysis for comparison to other alternatives presented in this report.

Table 16: Forced Draft Packed Column Air Stripper (Square Style) Capital Cost

CAPITAL COST					
ITEM NO.	DESCRIPTION	QUANTITY	UNITS	UNIT PRICE ($)	COST ($)
	Forced Draft Packed Column Air Stripper (Square Style)				
	CONSTRUCTION COSTS:				
1	Forced Draft Packed Column Air Stripper	2	LS	$130,000	$260,000
	Assumption: Two (2) units, second unit is considered a standby/redundant unit. Packed bed depth is 10 feet thick of Jaeger Tri-Pak #2 media and cross-sectional area is 12 feet by 12 feet. Blower capacity is 10,800 cfm, air/water ratio is 3.1 cfm/gpm, b				
2	Freight and Delivery to Jobsite , included in above	0	EA	$0	$0
3	On Site Loading/Unloading of Equipment	1	LS	$5,000	$5,000
4	Site Work	1	LS	$15,000	$15,000
5	Security Fencing/Gates	1	LS	$10,000	$10,000
6	Yard Piping	1	LS	$20,000	$20,000
7	Connection to Existing Plant Piping/Clearwell	1	LS	$15,000	$15,000
8	Treatment Building (40 ft x 50 ft x 20 ft)	2000	SF	$110	$220,000
9	Process Plumbing	1	LS	$15,000	$15,000
10	Electrical Sitework and Interior	1	LS	$25,000	$25,000
11	Electrical Controls: --SCADA System	1	LS	$20,000	$20,000
12	System Start-Up	1	LS	$15,000	$15,000
13	Training	1	LS	$5,000	$5,000
14	Mobilization/Demobilization	1	LS	$20,000	$20,000
	Subtotal-Construction Cost				**$645,000**
	Contingencies	25%			$161,300
	Total-Construction Cost				**$806,300**
	Professional Services/Indirect Costs:				
	Pre Design Testing/ Pilot Study	1	EA	$20,000	$20,000
	Project Management	6%			$48,400
	Engineering (Design & Construction Phase)	12%			$77,400
	Supervision & Administration/Construction	8%			$51,600
	Total-Professional Services/Indirect Costs				**$197,400**
	Total Opinion of Project Capital Cost				**$1,003,700**

Table 17: Forced Draft Packed Column Air Stripper (Square Style) Operation & Maintenance Cost

OPERATION AND MAINTENANCE COSTS				
DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	TOTAL
Forced Draft Packed Column Air Stripper (Square Style)				
ANNUAL OCCURRING COSTS:				
General System Operation and Maintenance:				
Labor Costs:				
Assumption: 2 hrs/day x 365 day/yr	730	HRS	$40	$29,200
System Performance Monitoring/Sampling:				
Assumption: 2 samples per event (one upstream and one downstream of train) x 1 process train x 1 event/month x 12 months/yr	24	SAMPLES	$125	$3,000
Power Costs:				
5 HP Blower				
Assumption: 5 HP x 0.746 kW/HP x 24 hrs/day x 365 days/year	32,675	kW	$0.10	$3,267
Miscellaneous Expenses	1	EA	$5,000	$5,000
Subtotal-General System O&M				**$40,467**
Total-Annual Occurring Costs				**$40,467**
NON-ANNUAL OCCURRING COSTS:				
	Project Years	Cost		
Media Cleaning				
Assumption: Remove and acid clean media packing, assuming 80 manhours per cleaning @ $40/MH and $1,000 in cleaning materials.	5, 10, 15, 20	$4,200		
Blower Rehabiliation	10, 20	$3,000		

Table 18: Forced Draft Packed Column Air Stripper (Square Style) Present Value Analysis

PRESENT VALUE ANALYSIS				
DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	TOTAL
Forced Draft Packed Column Air Stripper (Square Style)				
Total Project Cost Summary O&M Costs:				
Assumptions:				
Project Life	*20*	*yrs*		
Discount Rate	*3%*			
		Cash Flow	**Annuity**	**Present Value**
Project Capital Cost		$1,003,700		$1,003,700
Annual Occurring O&M Costs			$40,467	$602,054
Non-Annual Occuring O&M Costs:				
Year	5	$4,200		$3,623
Year	10	$7,200		$5,357
Year	15	$4,200		$2,696
Year	20	$7,200		$3,986
Total Present Value of Project				**$1,621,417**

Table 19: Forced Draft Packed Column Air Stripper (Cylindrical Style) Capital Cost

CAPITAL COST					
ITEM NO.	DESCRIPTION	QUANTITY	UNITS	UNIT PRICE ($)	COST ($)
	Forced Draft Packed Column Air Stripper (Cylindrical Style)				
	CONSTRUCTION COSTS:				
1	Forced Draft Packed Column Air Stripper	2	LS	$365,000	$730,000
	Assumption: Two (2) units, second unit is considered a standby/redundant unit. 138" diameter NSF-approved FRP Column standing 23'-9" tall. Packed bed depth is 12 feet thick. Blower is 20 horsepower. Requires a 50 HP transfer pump to integrate with exis				
2	Chemical Cleaning Package (serves both strippers)	1	LS	$70,000	$70,000
3	Freight and Delivery to Jobsite , included in above	0	EA	$0	$0
4	On Site Loading/Unloading of Equipment	1	LS	$5,000	$5,000
5	Site Work	1	LS	$15,000	$15,000
6	Security Fencing/Gates	1	LS	$10,000	$10,000
7	Yard Piping	1	LS	$20,000	$20,000
8	Connection to Existing Plant Piping/Clearwell	1	LS	$15,000	$15,000
9	Treatment Building (40 ft x 50 ft x 14 ft)	2000	SF	$80	$160,000
10	Process Plumbing	1	LS	$15,000	$15,000
11	Electrical Sitework and Interior	1	LS	$25,000	$25,000
12	Electrical Controls: --SCADA System	1	LS	$20,000	$20,000
13	System Start-Up	1	LS	$15,000	$15,000
14	Training	1	LS	$5,000	$5,000
15	Mobilization/Demobilization	1	LS	$20,000	$20,000
	Subtotal-Construction Cost				**$1,125,000**
	Contingencies	25%			$281,300
	Total-Construction Cost				**$1,406,300**
	Professional Services/Indirect Costs:				
	Pre Design Testing/ Pilot Study	1	EA	$20,000	$20,000
	Project Management	6%			$84,400
	Engineering (Design & Construction Phase)	12%			$168,800
	Supervision & Administration/Construction	8%			$112,500
	Total-Professional Services/Indirect Costs				**$385,700**
	Total Opinion of Project Capital Cost				**$1,792,000**

Table 20: Forced Draft Packed Column Air Stripper (Cylindrical Style) Operation & Maintenance Cost

OPERATION AND MAINTENANCE COSTS					
ITEM NO.	DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	TOTAL
	Forced Draft Packed Column Air Stripper (Cylindrical Style)				
	ANNUAL OCCURRING COSTS:				
	General System Operation and Maintenance:				
	Labor Costs:				
	Assumption: 2 hrs/day x 365 day/yr	730	HRS	$40	$29,200
	System Performance Monitoring/Sampling:				
	Assumption: 2 samples per event (one upstream and one downstream of train) x 1 process train x 1 event/month x 12 months/yr	24	SAMPLES	$125	$3,000
	Power Costs:				
	20 HP Blower				
	Assumption: 20 HP x 0.746 kW/HP x 24 hrs/day x 365 days/year	130,699	kW	$0.10	$13,070
	75 HP Transfer Pump				
	Assumption: 50 HP x 0.746 kW/HP x 24 hrs/day x 365 days/year	326,748	kW	$0.10	$32,675
	Miscellaneous Expenses	1	EA	$5,000	$5,000
	Subtotal-General System O&M				**$82,945**
	Total-Annual Occurring Costs				**$82,945**
	NON-ANNUAL OCCURRING COSTS:				
		Project Years	Cost		
	Media Cleaning				
	Assumption: Acid clean media packing with cleaning system, assuming 8 manhours per cleaning @ $40/MH and $1,000 in cleaning materials.	5, 10, 15, 20	$1,320		
	Blower Rehabiliation	10, 20	$3,000		
	Pump Rehabilitation	10, 20	$7,500		

Table 21: Forced Draft Packed Column Air Stripper (Cylindrical Style) Present Value Analysis

PRESENT VALUE ANALYSIS					
ITEM NO.	DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	TOTAL

Forced Draft Packed Column Air Stripper (Cylindrical Style)

Total Project Cost Summary O&M Costs:

Assumptions:

Project Life	*20*	*yrs*			
Discount Rate	*3%*				
			Cash Flow	**Annuity**	**Present Value**
Project Capital Cost			$1,792,000		$1,792,000
Annual Occurring O&M Costs				$82,945	$1,234,008
Non-Annual Occuring O&M Costs:					
Year	5		$1,320		$1,139
Year	10		$11,820		$8,795
Year	15		$1,320		$847
Year	20		$11,820		$6,544
Total Present Value of Project					**$3,043,334**

Table 22: Low-Profile Sieve Tray Air Stripper Capital Cost

CAPITAL COST					
ITEM NO.	DESCRIPTION	QUANTITY	UNITS	UNIT PRICE ($)	COST ($)
	Low-Profile Sieve Tray Air Stripper				
	<u>**CONSTRUCTION COSTS:**</u>				
1	Low-Profile Sieve Tray Air Stripper	5	LS	$65,000	$325,000
	<u>Assumption:</u> Five (5) parallel train units, fifth unit is considered a standby/redundant unit. Stainless steel construction, three (3) tray design, 12 feet by 6 feet tray footprint, approximately 8 feet total height. Demister included. Blower is 40 horse				
2	Freight and Delivery to Jobsite	2	LOADS	$10,000	$20,000
3	On Site Loading/Unloading of Equipment	1	LS	$10,000	$10,000
4	Site Work	1	LS	$15,000	$15,000
5	Security Fencing/Gates	1	LS	$10,000	$10,000
6	Yard Piping	1	LS	$20,000	$20,000
7	Connection to Existing Plant Piping/Clearwell	1	LS	$15,000	$15,000
8	Treatment Building (40 ft x 70 ft x 14 ft)	2800	SF	$80	$224,000
9	Process Plumbing	1	LS	$15,000	$15,000
10	Electrical Sitework and Interior	1	LS	$25,000	$25,000
11	Electrical Controls: --SCADA System	1	LS	$50,000	$50,000
12	System Start-Up	1	LS	$20,000	$20,000
13	Training	1	LS	$7,500	$7,500
14	Mobilization/Demobilization	1	LS	$20,000	$20,000
	Subtotal-Construction Cost				**$776,500**
	Contingencies	25%			$194,100
	Total-Construction Cost				**$970,600**
	<u>**Professional Services/Indirect Costs:**</u>				
	Pre Design Testing/ Pilot Study	1	EA	$20,000	$20,000
	Project Management	6%			$58,200
	Engineering (Design & Construction Phase)	12%			$116,500
	Supervision & Administration/Construction	8%			$77,600
	Total-Professional Services/Indirect Costs				**$272,300**
	Total Opinion of Project Capital Cost				**$1,242,900**

Table 23: Low-Profile Sieve Tray Air Stripper Operation & Maintenance Cost

OPERATION AND MAINTENANCE COSTS					
ITEM NO.	DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	TOTAL
	Low-Profile Sieve Tray Air Stripper				
ANNUAL OCCURRING COSTS:					
	General System Operation and Maintenance:				
	Labor Costs: *Assumption: 2 hrs/day x 365 day/yr*	730	HRS	$40	$29,200
	System Performance Monitoring/Sampling: *Assumption: 5 samples per event (one combined upstream and one downstream of each of 4 trains) x 1 event/month x 12 months/yr*	60	SAMPLES	$125	$7,500
	Power Costs: 40 HP Blower *Assumption: 24 HP x 0.746 kW/HP x 24 hrs/day x 365 days/year*	156,839	kW	$0.10	$15,684
	Tray Cleaning: *Assumption: Powerwash and acid clean (if necessary) stripper trays assuming 8 manhours per unit @ $40/MH and $250 in cleaning materials.*				$1,850
	Miscellaneous Expenses	1	EA	$5,000	$5,000
	Subtotal-General System O&M				**$59,234**
	Total-Annual Occurring Costs				**$59,234**
NON-ANNUAL OCCURRING COSTS:					
		Project Years	Cost		
	Blower Rehabiliation	10, 20	$3,000		

Table 24: Low-Profile Sieve Tray Air Stripper Present Value Analysis

PRESENT VALUE ANALYSIS					
ITEM NO.	DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	TOTAL
	Low-Profile Sieve Tray Air Stripper				
	Total Project Cost Summary O&M Costs:				
	Assumptions:				
	Project Life	*20*	*yrs*		
	Discount Rate	*3%*			
			Cash Flow	**Annuity**	**Present Value**
	Project Capital Cost		$1,242,900		$1,242,900
	Annual Occurring O&M Costs			$59,234	$881,251
	Non-Annual Occuring O&M Costs:				
	Year	10	$3,000		$2,232
	Year	20	$3,000		$1,661
	Total Present Value of Project				**$2,128,044**

5.3 *Comparison of Treatment Alternatives*

A summary of the treatment alternatives evaluated in this report is provided below:

Table 25: Treatment Alternatives Summary

FACTOR	GRANULAR ACTIVATED CARBON ADSORPTION	AIR STRIPPERS		
		PACKED COLUMN (Square)	PACKED COLUMN (Cylindrical)	LOW-PROFILE SIEVE TRAY
No. of Units	12	2	2	5
Process Configuration	Six parallel trains of 2 units in series (6th train is redundant)	Two (2) parallel trains of single units (2nd train is redundant)	Two (2) parallel trains of single units (2nd train is redundant)	Five parallel trains of single units (5th train is redundant)
Unit Capacity	695 gpm/train	3, 475 gpm	3, 475 gpm	1,000 gpm/unit
Unit Size *(approximate)*	10-12 ft Dia. x 16-18 ft H per vessel	12 ft x 12 ft in x 20 ft H	11.5 ft Dia x 24 ft H	12.5 ft x 6.5 ft x 6 ft H
Features	20,000 lbs of carbon per vessel	10 ft depth of Jaeger Tri-Pack #2 media	12 ft of Delta Pak media	3 aeration trays per unit
Other	Painted carbon steel with cross-over piping/control	Aluminum housing 5 HP Blower (10,800 cfm)	FRP construction, 20 HP Blower, Chemical cleaning system	Stainless steel construction, 40 HP blower (3,500 cfm), 1,000 gal sump
Capital Cost	$2,588,900	$1,003,700	$1,792,000	$1,242,900
Present Value of O&M Cost *(20 yrs)*	$4,045,689	$617,717	$1,251,334	$885,144
Total Present Value Cost	**$6,634,589**	**$1,621,417**	**$3,043,334**	**$2,128,044**
Considerations	• Installed D.S. of high service pumps • Largest building required • High cost of carbon replacement	• Assumes no pumping required- borderline as to whether it is required • Lowest overall cost • Media cleaning less difficult than cylindrical version	• Requires pumping to or from unit because of height • Highest cost of air stripper options. • Media cleaning more difficult than square version • Access is difficult Not completely housed in building	• Requires no pumping because of low height • Second lowest overall cost • Tray cleaning is much less difficult than media cleaning Better operating flexibility with four operating trains.

6 RECOMMENDATION

Both non-treatment and treatment alternatives are evaluated in this report. The non-treatment wellfield pumping management may provide a short-term approach to deal with the contaminant plume until more reliable TCE treatment provisions can be constructed and incorporated into the treatment provide at the City of Forrest City Water Treatment Plant #1. This approach has been utilized to some extent already by the Utility Staff.

A more long-term and predictable approach to the TCE problem for the City of Forrest City would be to construct and operate a TCE treatment system at Water Treatment Plant #1. TCE reduction at the anticipated levels is quite easily accomplished by the conventional technologies evaluated in this report. Treatment by liquid phase granular activated carbon (GAC) and air stripping are the most prevalent methods. The cost-effectiveness of GAC systems typically comes down to the design flowrate and expected treated water volume. GAC is exhausted as the TCE is adsorbed to the surface of the carbon and as a result requires eventual removal, disposal and replacement. The cost for this operation and maintenance consideration many times makes GAC treatment less cost effective in a present value cost analysis than air stripping for larger design flows.

Air stripping is the recommended treatment process for TCE reduction for the City of Forrest City WTP #1. Several alternative styles for air strippers are evaluated resulting in a projected present value cost for a 20-year project life of $1.6M to $3.1M. Packed tower (square and cylindrical geometries) and low-profile sieve tray styles both offer reliable and efficient treatment options. The cylindrical style packed tower in this case has the both the highest capital cost and operation and maintenance cost of the options evaluated.

Both the packed tower (square style) and the low-profile sieve tray strippers offer essentially equivalent alternatives. The ultimate selection should be based upon more design development and closer examination of the existing water treatment plant piping elevations and the flexibility of incorporating either of these two into the existing treatment process without requiring pumping provisions. The choice should be made to locate the stripper into the originally-designed treatment process flow in the event that softening is ever resumed at this facility and to do so without the need to pump to or from the unit(s). It would appear that since the low-profile sieve tray stripper is much shorter than the packed tower (square style) that it should be the technology of choice.

Physical variations should also be examined with potential vendors during the design phase. The height of the packed tower (square style) stripper could possibly be reduced if the footprint is expanded. Additional considerations for assisting in periodic cleaning should also be investigated during the design phase in an effort to reduce overall operating and maintenance costs of either system.

APPENDIX

NONE